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Pre-season run size forecasts for Fraser River Sockeye (*Oncorhynchus nerka*) and Pink (*O. gorbuscha*) salmon in 2013

Prévisions d'avant-saison concernant le volume de la montaison du saumon rouge du fleuve Fraser (*Oncorhynchus nerka*) et du saumon rose (*O. gorbuscha*) en 2013

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ABSTRACT

Salmon forecasts remain highly uncertain, in large part due to wide variability in annual salmon productivity (recruits-per-spawner). For Fraser Sockeye, quantitative and qualitative indicators of productivity explored to date have not reduced forecast uncertainty and remain an active area of research. Fraser Sockeye forecasts have been particularly uncertain in recent years, due to the systematic declines in productivity exhibited by most stocks, which culminated in one of the lowest productivities on record in the 2005 brood year (2009 four year old and 2010 five year old returns). Subsequently (2010 to 2012 return years), productivity appears to have improved.

Similar to previous years, models selected for each stock in the 2013 forecast were chosen for their relative ability to predict true returns over the full stock-recruitment time series. Each model was compared to a suite of forecast models, which exclude the recent productivity model forms introduced in the 2010 forecast. Comparative rankings of model performance were obtained from the 2012 jackknife analysis output. A sensitivity analysis was also conducted to compare the 2013 forecasts with forecasts produced using top ranked models evaluated over the low productivity period (brood years 1997 to 2005) and includes 2010 recent productivity models.

To capture inter-annual random (stochastic) variability in Fraser Sockeye productivity, forecasts are presented as standardized cumulative probabilities (10%, 25%, 50%, 75%, and 90%). The 2013 forecast indicates a one in ten chance (10% probability) the total Fraser Sockeye return will be at or below 1,554,000 (lowest observed on this cycle) and a nine in ten chance (90% probability) it will be at or below 15,608,000, assuming productivity is similar to past observations. The mid-point of this distribution (50% probability) is 4,765,000 (there exists a one in two chance the return will be at or below this value). The four year old percentage of the total forecast is 91%, and ranges from 13% to 100%, depending on the stock. For the 2013 forecast, Raft, Harrison, and North Thompson miscellaneous stocks were moved into the Summer Run timing group, due to changes in the migration timing of these stocks, which is consistent with a recent decision by the Fraser Panel of the Pacific Salmon Treaty process.

Summer Run stocks, particularly Chilko & Quesnel, contribute 78% to the total return forecast, whereas Late Run (12%), Early Summer (5%) and Early Stuart Run stocks (4%) each contribute considerably less. The Harrison forecast for 2013 is particularly uncertain, and the return for this stock could fall outside the forecast range. The total forecasted 2013 Fraser Sockeye return largely falls (up to a three in four chance, based on past observations) below the cycle average (8.6 million), due to the below average 2009 and 2008 brood year escapements for most stocks. Conversely, there is a one out of four chance the return will be above the cycle average, if Fraser Sockeye productivity falls at the high end of past observations. If low productivity conditions resume, returns could be considerably lower than forecast, based on a sensitivity analysis forecast that ranges from 523,000 to 5,419,000 at the 10% to 90% probability level.

For Fraser Pink Salmon, the forecast ranges from 4,794,000 to 17,111,000 fish at the 10% to 90% probability levels (Table 1). The median (50% probability) forecast of 8,926,000 Pink Salmon is below the long-term (1959-2011) average return (12.6 million) (Table 1). The Fraser Pink forecast is highly uncertain given the changes in the methods used to estimate returns through time.

RÉSUMÉ

Les prévisions pour le saumon demeurent hautement incertaines en raison surtout de la grande variabilité de la productivité annuelle du saumon (recrues par reproducteur). Dans le cas du saumon rouge du fleuve Fraser, les indicateurs quantitatifs et qualitatifs de productivité examinés jusqu'à aujourd'hui n'ont pas dissipé l'incertitude des prévisions et demeurent un domaine de recherche actif. En particulier, les prévisions pour le saumon rouge du fleuve Fraser ont été marquées d'incertitude au cours des dernières années en raison de la baisse systématique de la productivité de la plupart des stocks. La productivité durant l'année d'éclosion 2005 a été parmi les plus faibles de toute l'histoire (montaisons des saumons de quatre ans en 2009 et de cinq ans en 2010). Par la suite (les années de montaison de 2010 à 2012), la productivité semble s'être améliorée.

Comme les années précédentes, c'est la capacité de prévoir le volume de montaison au cours de séries chronologiques complètes du recrutement qui a déterminé le choix des modèles pour les prévisions de 2013 de chaque stock. Chaque modèle a été comparé à une série de modèles de prévision, qui exclut les récents modèles de la productivité introduits dans les prévisions de 2010. On a obtenu le classement relatif des modèles selon leur rendement grâce aux résultats de l'analyse jackknife. On a également mené une analyse de sensibilité comparant les prévisions de 2013 et les prévisions réalisées à l'aide des meilleurs modèles évalués pendant la période de faible productivité (années d'éclosion de 1997 à 2005), y compris les récents modèles de productivité.

Pour appréhender la variabilité aléatoire (stochastique) interannuelle de la productivité du saumon rouge du fleuve Fraser, les prévisions sont présentées sous forme de probabilités cumulatives normalisées (10 %, 25 %, 50 %, 75 % et 90 %). Les prévisions de 2013 indiquent qu'il y a une chance sur dix (probabilité de 10 %) que la montaison totale du saumon rouge du fleuve Fraser soit de 1 554 000 individus ou moins (le chiffre le plus bas observé au cours de ce cycle), et qu'il y a neuf chances sur dix (probabilité de 90 %) qu'elle soit de 15 608 000 individus ou moins, si l'on suppose une productivité semblable à celle des observations antérieures. La valeur médiane de cette répartition (probabilité de 50 %) est de 4 765 000 individus (il y a une chance sur deux que les montaisons soient égales ou inférieures à cette valeur). Le pourcentage total des individus de quatre ans pour les prévisions totales est de 91 % et se situe entre 13 % et 100 % selon les stocks. Pour les prévisions de 2013, les divers stocks des rivières Raft, Harrison et North Thompson font maintenant partie du groupe de montaison d'été en raison de la modification de la période de montaison de ces stocks, ce qui est conforme à une décision récente du Conseil du fleuve Fraser de la Commission du saumon du Pacifique.

Les stocks de montaison estivale, notamment Chilko et Quesnel, représentent 78 % des prévisions de montaison totales, par rapport aux chiffres considérablement inférieurs des stocks de montaison tardive (12 %), hâtive d'été et hâtive de la Stuart (4 %). Les prévisions de 2013 pour la Harrison sont marquées d'incertitude et les données de montaison pour ce stock pourraient se situer en dehors de la fourchette prévue. Les prévisions de la montaison totale du saumon rouge du fleuve Fraser en 2013 se situent (jusqu'à trois chances sur quatre, selon les observations antérieures) bien en dessous de la moyenne du cycle (8,6 millions) en raison des échappées inférieures à la moyenne de la plupart des stocks de montaison au cours des années d'éclosion 2008 et 2009. Par contre, il existe une chance sur quatre que la montaison soit supérieure à la moyenne du cycle si la productivité du saumon rouge du Fraser se situe dans la fourchette supérieure des observations antérieures. Si les conditions de productivité faible se reproduisent, les montaisons pourraient être considérablement inférieures aux prévisions, d'après une analyse de sensibilité qui prévoit entre 523 000 et 5 419 000 poissons selon des niveaux de probabilité de 10 % à 90 %.

Quant au saumon rose du fleuve Fraser, les prévisions se situent entre 4 794 000 et 17 111 000 poissons selon des niveaux de probabilité entre 10 % et 90 % (tableau 1). La prévision moyenne (probabilité de 50 %) de 8 926 000 saumons roses se situe en dessous de la moyenne des montaisons de longue date (1959-2011) (tableau 1). Les prévisions pour le saumon rose du fleuve Fraser sont très incertaines en raison des différentes méthodes utilisées pour estimer les montaisons au fil du temps.

INTRODUCTION

FRASER SOCKEYE

Overview of Fraser Sockeye Forecasts

Pre-season return forecasts are produced annually for 19 Fraser Sockeye stocks and six additional miscellaneous stock groups using a suite of forecast models. To capture inter-annual random (stochastic) uncertainty in Fraser Sockeye forecasts (largely attributed to variations in stock productivity), forecasts are presented as standardized cumulative probabilities (10%, 25%, 50%, 75%, and 90%) using Bayesian statistics for biological models or residual error for non-parametric models, rather than as single deterministic point estimates (Grant et al. 2010). At the 25% probability level, for example, there is a one in four chance the actual return will fall at or below the specified return prediction, given the historical data. Fisheries and Oceans Canada (DFO) fisheries managers use these forecast probability distributions to frame out the range of fishing opportunities that stakeholders may expect in the upcoming year. The return forecasts are also applied in concert with run timing forecasts as Bayesian priors for test-fishery and hydro-acoustic models, which are used to manage the fisheries in-season. As the season proceeds and more in-season data become available, the pre-season forecasts have a diminishing influence on in-season return estimates.

The 2013 Fraser Sockeye forecast follows the same approach as the 2012 forecast (MacDonald and Grant 2012; DFO 2012 b), which was adapted from methods described in earlier forecasts (Cass et al. 2006; DFO 2006; DFO 2007; DFO 2009; Grant et al. 2010; DFO 2012a; Grant & MacDonald 2012). Key aspects of this approach include the following:

1) a single forecast scenario is presented, which uses the most appropriate model for each stock based on model performance over the full stock-recruitment time series (long-term model performance scenario);
2) the full suite of applicable candidate models (excluding the recent productivity RS4yr, RS8yr and KF models introduced in Grant et al. (2010)) was evaluated for each stock;
3) a jackknife (leave-one-out) cross-validation (CV) analysis was used to generate the historical forecast time series' for each stock and model for the model evaluation process (Appendix 1 in MacDonald & Grant 2012);
4) the model selection process and criteria used to select the 2013 forecast model for each stock were identical to the 2012 forecast (see MacDonald & Grant 2012);
5) an additional sensitivity analysis was conducted to examine model performance for each stock over only the more recent period of low productivity (1997-2004 brood years) (Appendix 1).

Most forecast models used for Fraser Sockeye rely on brood year spawner abundances or juvenile data to predict returns, though some models predict future returns using exclusively past return data (Table 4). Given that there are a number of both non-parametric and biological model forms that can be used to generate annual forecasts, model performance was evaluated for each stock using jack-knife analysis and a suite of performance measures. In short, each performance measure ranks models against one another according to how well (how precise and/or accurate) they predict true returns. For each stock, the model used to generate the 2013 forecast was selected based on the model rank and the model selection process presented in the 2012 forecast (MacDonald & Grant 2012).

The 2013 forecast scenario evaluates all applicable models for each stock, excluding the recent productivity models added in the 2010 forecast process (see Methods), using all available stock-recruitment data (typically brood years 1948-2004). Miscellaneous stocks, for which recruitment

data are unavailable, were forecast using the product of their brood year escapements and the long-term (full stock-recruitment time series) average productivity of spatially and temporally similar stocks with stock recruitment data (index stocks), as identified in Table 1. Following the extremely low return in 2009, the 2010 and 2011 forecasts were presented as two explicit scenarios: (1) the full suite of models were evaluated across each stock's full stock-recruitment time series ('Long-Term Productivity' scenario, termed "Long-term Model Performance" in 2012) and (2) the full suite of models were evaluated across each stock's recent (generally low) productivity period ('Recent Productivity' scenario, termed "Recent Model Performance" in 2012). Given that forecasts corresponding to the "Long-term Model Performance" scenario have performed better than forecasts for the "Recent Model Performance" scenario in most recent years (2010 to 2012; Figure 4), the "Long-term Model Performance" scenario was used for the 2013 forecasts.

However, similar to the 2012 forecast, 2013 forecasts are provided for the "Recent Model Performance" scenario as an additional sensitivity analysis. This analysis evaluated model performance over the recent, generally low productivity period (1997-2004 brood years) by stock, rather than over the full range of productivities observed over the entire time series (Appendix 1). This analysis also included recent productivity models introduced in the 2010 forecast process, in contrast to the 2013 forecast which excludes these models. All other methods used to select the final forecast for the sensitivity analysis were identical to the 2013 forecast process. Miscellaneous stocks, for which recruitment data is unavailable, were forecast using the product of their brood year escapements and the average recent (brood years 1997-2004) productivity for spatially and temporally similar stocks with stock recruitment data (index stocks), as identified in Table 1.

Historical Fraser Sockeye Returns

Fraser Sockeye returns have historically varied, due to the four-year pattern of abundances (cyclic dominance) observed for many stocks, and variability in annual productivity (recruits per spawner) (Figures 1 A & B). In recent years, Fraser Sockeye have exhibited particularly large variations in total returns. The 2009 return (~1.6 million) and 2010 return (~30 million) were respectively, amongst the lowest (2009 cycle average: ~8.6 million) and highest (2010 cycle average: ~12 million) returns on record for their cycles. Subsequently, returns in 2011 (~5.1 million) and 2012 (~2.2 million) (Figure 1 A) were more similar to their respective cycle averages of 5.1 million and 3.6 million. The large difference between the record high return in 2010, and the closer to average returns in 2011 and 2012, is attributed to brood year escapements (adult spawners in the parental generation as an index of egg abundance), rather than differences in stock productivity. For the 2010 return, the associated 2006 brood year escapement was relatively high (~5 million compared to the cycle average of 1.7 million), driven by the dominant cycle of the Adams River stock. In contrast, lower returns in 2011 are attributed to the lower 2007 brood year escapements (900,000 compared to the cycle average of 700,000). Similarly, low returns in 2012 are also attributed to lower 2008 brood year escapements (300,000 compared to the cycle average of 500,000).

To provide context for the 2013 forecast, the average returns of Fraser Sockeye on the 2013 cycle are presented in Table 1 (column G). The 2013 cycle has the second largest average return of the four cycles of Fraser River Sockeye, with an average annual return (1953-2009) of 8.6 million for all 19 forecasted stocks combined. Quesnel (Summer Run) has historically been the main driver of returns on this cycle line, accounting for 46% of the total on average. Late Stuart, Chilko, and Early Stuart have also contributed relatively high proportions to the 2013 cycle average, at 19%, 9% and 9% respectively. Stocks that have each comprised greater than 2% (~3% each) of the average return on the 2013 cycle include Stellako, Weaver and Birkenhead. All remaining stocks have contributed less than 2% to the average return for this cycle.

Fraser Sockeye Escapement in the 2008 and 2009 Brood Years

Most Fraser Sockeye return as four year old fish after spending two winters in freshwater and two winters in the marine environment (Gilbert-Rich aging convention: 4_2). Therefore, the majority of Sockeye returning in 2013 will be recruited from eggs spawned by adults in 2009 (brood year). Since this brood year was associated with one of the lowest returns on record (see previous paragraph), escapements, as a result, were low for most stocks in 2009. Most Fraser Sockeye stocks also have a five year old (5_2) component that contributes, on average, 20% to their total recruitment. For five year olds returning in 2013, their brood year (2008) was also associated with particularly low returns and escapements.

Overall, the number of effective female spawners (EFS) in the 2009 brood year (511,000 EFS) was by far the lowest on the 2013 cycle since 1977 (2009 cycle average: 1.1 million). For approximately half of the stocks (9 out of 19), 2009 brood year EFS or smolt (Chilko & Cultus) abundances were well below their cycle averages (1949-2005 time series for most stocks) (Table 1, column C). Three stocks (Chilko, Quesnel & Harrison) together contributed 62% (25%, 17% and 20% respectively) of the total 2009 brood year EFS. The Early Stuart, Pitt, Late Stuart, Late Shuswap and Birkenhead stocks each contributed between 4% and 9% to the total EFS. All remaining stocks contributed less than 4% to the total EFS.

Similarly, the number of EFS in the 2008 brood year (300,000 EFS) was also amongst the lowest on the 2012 cycle. For most stocks (12 out of 18, which excludes Harrison as it does not have a five year old component), EFS or smolt (Chilko & Cultus) abundances in 2008 were well below their cycle average (1948-2004 for most stocks) (Table 1, column D). Many of these brood year escapements were the lowest or amongst the lowest on record for these stocks. For the remaining 6 out of 18 stocks, 2008 EFS abundances were close to, or above, their cycle average (1948-2004 for most stocks) (Table 1, column D). Three Summer Run stocks (Stellako, Chilko & Late Stuart) contributed the greatest overall proportion (71%: ~ 24% each) to the total 2008 EFS.

Harrison Sockeye have a unique age structure compared to other Fraser Sockeye stocks. This stock is comprised of three and four year old fish with varying inter-annual proportions. Higher proportions of four year olds occur in odd (Fraser Pink salmon) years (Grant et al. 2011). The brood years contributing to Harrison returns in 2013 include 2009 and 2010, which were both well above previously observed escapements for this stock (Table 1, columns C & D).

Given the below average brood year escapements for most stocks in 2008 and 2009, there is a 75% chance the 2013 returns will be at or below average for most Fraser Sockeye stocks. One key exception is Harrison Sockeye, where brood year escapements are well above the highest previously observed values, and therefore, forecasts for this stock are highly uncertain.

Fraser Sockeye Productivity Trends

In recent decades, total productivity (recruits-per-spawner) across all Fraser Sockeye stocks has generally declined (Figure 1 B), though individual stock trends vary (Grant et al. 2010; Grant et al. 2011; Peterman & Dorner 2011; Peterman & Dorner 2012). One notable exception is Harrison Sockeye, which have increased in productivity in recent years (Grant et al. 2010; Grant et al. 2011). Harrison Sockeye have a unique age-structure and life-history compared to all other stocks. This stock migrates to the ocean shortly after gravel emergence (most other Sockeye rear in lakes for one to two years prior to ocean migration) and returns as three and four year old fish (most other Sockeye return as four and five year olds). During outmigration, Harrison Sockeye juveniles also generally enter the Strait of Georgia later than all other stocks (Birtwell 1987), spend longer rearing in the Strait of Georgia than other stocks (Tucker et al.

2009), and generally migrate into the North Pacific via the Juan de Fuca Strait (other stocks migrate North through the Johnstone Strait).

For most Fraser Sockeye stocks, declining productivity trends culminated in some of the lowest productivities on record in the 2005 brood year (Figure 3), including Harrison (which has otherwise increased in productivity in recent years). Subsequently, productivity appears to have improved for most stocks in the 2006 to 2008 brood years (2010 to 2012 return years for most of these Sockeye) (Figure 4).

Although for most Fraser Sockeye stocks (with exceptions such as Late Shuswap, Weaver, Raft, and Harrison) productivity has declined, and reached the lowest values on record in the 2005 brood year, in subsequent brood years productivity has improved. Despite on-going research, biological or environmental indicators of Fraser Sockeye productivity are currently limited, therefore, Fraser Sockeye productivity through 2013 remains uncertain.

FRASER RIVER PINK SALMON

Fraser River Pink Biology

The Fraser River has the largest population of Pink Salmon in the northeast Pacific, south of Alaska. Between 1947 and 1987 the average odd year return was 11,500,000 Pinks (Pess et al. 2012). Fraser River Pinks are also the largest Pinks in North America in terms of physical size, though they have decreased in size since the 1950's (Heard 1991). Fraser River Pink salmon return as two-year old fish, spawning in odd years. Historic records of the abundant odd-year Fraser Pink run date back to the 19th century (Ricker 1989). While an even year run may possibly exist, its presence is uncertain, and is not indicated in the early records (Holtby & Ciruna 2007; Ricker 1989). Many other systems have only one brood line of Pink salmon, or have one brood line that is much larger than the other. In British Columbia, the abundant populations generally return on odd years in the southern portion of their range, while northern populations return in even years (Ricker et al 1978).

Fraser Pink fry emerge from the gravel in early spring, as early as February, and migrate immediately to the Fraser estuary (FRAP 1995; Grant & Pestal 2009). Subsequently, they migrate through the Strait of Georgia into the North Pacific where they rear for one year (FRAP 1995; Grant & Pestal 2009) before returning to the Fraser watershed to spawn.

Returns, Escapement, Catch, Fry Abundance and Productivity

Fraser Pink salmon spawn in both the mainstem and tributaries of the Fraser River; some populations migrate up to 370 km from the Fraser River estuary (Hurley and Woodall 1968). Pink salmon generally return to the lower Fraser River between August and late September (FRAP 1995), migrating primarily through the Juan de Fuca Strait, though approximately 30% deviate through Johnstone Strait in most years.

In the early 1900's, millions of Pink salmon reportedly spawned above Hells Gate, in Seton Creek, and the Thompson and Nicola Rivers (FRAP 1995). In 1913, the Hells Gate landslide blocked almost all migration of Pink salmon to these upriver spawning areas (FRAP 1995). The landslide dumped large quantities of rock into the river at Hells Gate, narrowing the channel and changing the velocity, height, and turbulence of the river (Roos 1991). After the landslide cut off access upriver, the overall population of Fraser Pink salmon declined dramatically (Pess et al 2012). Pink salmon were not seen spawning upriver of Hells Gate until 1923 when they were found in Seton Lake and the Thompson River (Williams et al 1986). Pinks were periodically able to pass through Hells Gate in the years following 1923, though their presence was not consistent (Roos 1991). Fishways were constructed by 1947, and over the next two cycles Pink

salmon again began to appear in steady numbers above Hells Gate (Pess et al 2012; Ricker 1989; Roos 1991; Withler 1982), though overall abundances remained low (approx. 1/3 of pre-1913 abundances) throughout the 1950's (Roos 1991).

From 1957 to 1981 Pink abundances increased and also expanded spatially (Pess et al. 2012), though upriver runs experienced lower productivity than those downriver, potentially due to difficulties with upstream migration and human impacts on spawning streams (Ricker 1989). The time-series of Fraser Pink returns begins in this earlier period of low abundances (6.3 million on average from 1959 to 1997) relative to more recent years (15.1 million on average from 1998 to 2009) (Figure 6). Increases in abundance later in the time series are likely attributed to Fraser Pink expansion into the upper Fraser watershed (Pess et al. 2012). Additionally, a shift in environmental conditions after 1976 increased stock productivity, which resulted in increases in abundance of downstream Pink salmon that provided a larger source population for upstream strays (Pess et al 2012).

Average Pink escapements similarly increased from a low of 1.6 million in the early time series (average from 1959 to 1997), to 9.1 million in the later time series (average from 1979 to 2011) (Figure 6). In recent years, escapements have not been measured directly on the spawning grounds, but are calculated using test fishery return minus catch estimates. Therefore, in recent years escapement estimates are highly uncertain, and, as a result, are not used in the forecast process. In recent years (2001 to 2011), escapements have also been particularly high (average escapement: 14.7 million Pinks). In 2011, the Fraser Pink escapement was 10.5 million, which is greater than the time-series average (6.3 million from 1959 to 2011).

The recent increase in Pink escapement is in part due to declines in catch. Fraser Pink catch was particularly high early in the time series (1959 to 1997) at 6.8 million on average, and dropped to 1.7 million in the later time series (1979 to 2011) (Figure 6). Smaller catches of Fraser Pink salmon in recent years are attributed to the decline in commercial interest in this species, and the lack of commercial fishing opportunities for Pinks imposed by harvest constraints enacted to protect steelhead and Late Run Fraser Sockeye. There has however, been a growing interest in Pink harvest in the last few years.

Fraser Pink fry abundances are estimated at Mission during their downstream migration, consistent with methods developed in 1962 (Vernon 1966). Given the high uncertainty in Pink escapement estimates in recent years, fry abundance is used as the predictor variable in the forecast process. Similar to the escapement time-series, Pink fry abundances were low (average: 270 million) early in the time-series (1961 to 1977) (Figure 7) and subsequently increased (400 million from 1979 to 2001). Pink fry abundances have been particularly high in recent years (632 million from 2003 to 2011). The Pink fry abundance from the 2011 brood year (used for the 2013 forecast) was 519 million, which was below the recent average of 632 million, but above the time series average of 400 million.

METHODS

FRASER SOCKEYE FORECASTS

All biological and environmental data, biological and non-parametric models, and results of model ranks are identical to those presented in MacDonald & Grant (2012). The last brood year for which full recruitment data (four and five year olds) are available is 2005, with the exception of Harrison Sockeye, which given its unique age structure has recruitment data available to the 2006 brood year. Five year old recruit data for the 2005 brood year are preliminary, however they were used since this poorer quality data has a limited influence on the total recruits, attributed to the low proportion of five year olds in the total recruitment. Recent return data (2009 to 2012) are currently being reviewed by the Fraser River Panel technical working group (as part of the Pacific Salmon Treaty process). At present, the 2009 and 2010 return data are

available in only a preliminary form, and further changes may occur after completion of the 2013 forecast. Return data for 2011 and 2012 are not yet available.

Late Shuswap (fall fry) juvenile data were not used in the 2013 forecast process since field surveys were not conducted to estimate fry production from the 2008 and 2009 brood years. Quesnel (fall fry) juvenile data were only available for the 2009 brood year, therefore only four year old 2013 forecasts could be produced using models with a fry predictor variable for this stock. Escapement and wild smolt (Cultus and Chilko) data were provided by DFO Fraser Stock Assessment (DFO, Keri.Benner@dfo-mpo.gc.ca), channel fry data (Nadina and Weaver) were provided by DFO Oceans, Habitat & Enhancement Branch (DFO, David.Willis@dfo-mpo.gc.ca), Cultus hatchery smolt numbers (released downstream of the Sweltzer Creek enumeration fence) were obtained by DFO Oceans, Habitat and Enhancement Branch (Catherine.McClean@dfo-mpo.gc.ca), and recruitment data were provided by the Pacific Salmon Commission (PSC) (Lapointe@psc.org).

The only change in methods for the 2013 forecast, from the 2012 forecast (MacDonald & Grant 2012), was in the suite of models evaluated for each stock. For the 2013 forecast, three model forms introduced in Grant et al. (2010) to capture recent productivity conditions (RS4yr, RS8yr, KF) were excluded from consideration. Since productivity appears to have improved in the more recent brood years (the 2006 to 2008 brood years, corresponding to, the 2010 to 2012 return years), and stock-recruitment data are not yet available for these recent years to capture this change in productivity, these models were not included in the 2013 model suite. These models were considered in the 'Recent Model Performance' sensitivity analysis to reflect returns under this lower productivity assumption, since future productivity remains uncertain.

FRASER PINK FORECASTS

Fraser Pink forecast models were previously evaluated using retrospective analysis (DFO 2006). The first ranked model is a power-juv model with a covariate of sea surface salinity at Race Rocks (Juan de Fuca Strait) and Amphitrite Point (West Coast Vancouver Island) lighthouse stations from July to September. Sea surface salinity data are available at the following DFO website: (http://www.pac.dfo-mpo.gc.ca/science/oceans/data-donnees/lighthouses-phares/index-eng.htm), with the exception of the 2011 brood year (2012 ocean entry year), which was provided separately (P. Chandler, DFO, pers. comm). The second ranked model is a power-juv model (no covariates). Model form descriptions are presented in the appendices of Grant et al. (2010). All Fraser Pink forecast models rely on juvenile fry abundance, as escapement estimates are no longer obtained for this species. From 1961 to 2001, recruitment was obtained from separate catch and escapement assessment programs. Within this period, escapement programs changed from system specific (e.g. Lower Fraser, Fraser Canyon, Upper Fraser, Seton-Anderson, Thompson, Harrison, Vedder-Chilliwack) estimates (1961 to 1991), to a single system-wide Fraser River estimate (1993-2001). Post-2001, escapement programs have no longer been conducted on the Fraser mainstem due to fiscal constraints. Total returns are estimated from in-season test fishery programs.

For the 2013 Pink forecast, juvenile fry data (estimated in a Mission downstream trap program) were updated to include the 2012 outmigration year (used as the predictor variable in Pink salmon biological models). The 2012 fry abundance (520 million) was above average (400 million). Recruitment data were updated to include the 2009 brood year (2011 return year) (B. White, Pacific Salmon Commission, pers. comm.).

FORECAST RESULTS

OVERVIEW OF THE 2013 FRASER SOCKEYE AND PINK RETURNS

Fraser Sockeye forecasts for 2013 are associated with relatively high uncertainty, in large part due to wide variability in annual salmon productivity (recruits-per-spawner), and observation error in the stock-recruitment data. High forecast uncertainty is consistent with previous Fraser Sockeye forecasts (Cass et al. 2006; DFO 2006; DFO 2007; DFO 2009; Grant et al. 2010; DFO 2012a; Grant & MacDonald 2012; DFO 2012 b; MacDonald & Grant 2012) and recent research conducted on coast-wide salmon stocks (Haeseker et al. 2007 & 2008). Fraser Sockeye forecasts have been particularly uncertain in recent years, due to the systematic declines in productivity exhibited by most stocks, which culminated in amongst the lowest productivity on record in the 2005 brood year (2009 four year old and 2010 five year old returns). Subsequently (2010 to 2012 return years), productivity appears to have improved. Given the absence of leading quantitative or qualitative indicators of Fraser Sockeye productivity, stochastic (random) uncertainties associated with the 2013 Fraser Sockeye forecasts are presented as a series of forecasted values that correspond to standardized cumulative probabilities (10%, 25%, 50%, 75%, and 90%). The 50% (median) probability level is the mid-point of the forecast distribution, indicating a one in two chance that Fraser Sockeye returns will be at or below these values, assuming stock productivity is similar to past observations.

The 2013 forecast indicates a one in ten chance (10% probability) the total Fraser Sockeye return will be at or below 1,554,000 and a nine in ten chance (90% probability) it will be at or below 15,608,000, assuming productivity is similar to past observations (Tables 1 & 2). The mid-point of this distribution (50% probability) is 4,765,000 (there exists a one in two chance the return will be at or below this value). The four year old percentage of the total forecast is 91% (ranges from 13% to 100%, depending on the stock). For the 2013 forecast, Raft, Harrison, and North Thompson miscellaneous stocks were moved into the Summer Run timing group, due to changes in the migration timing of these stocks, which is consistent with a recent decision by the Fraser Panel of the Pacific Salmon Treaty process.

Summer Run stocks, particularly Chilko & Quesnel, contribute 78% to the total return forecast, whereas Late Run (12%), Early Summer (5%) and Early Stuart Run stocks (4%) each contribute considerably less. The Harrison forecast (Summer Run timed) is particularly uncertain, as the 2009 and 2010 brood year escapements for this stock are well above the observed range. Additionally, Harrison Sockeye exhibit high variability in their age proportions from year to year. Therefore, it is possible that the Harrison return may fall outside the forecast range. The total forecasted 2013 Fraser Sockeye return largely falls (up to a three in four chance, based on past observations) below the cycle average (8.6 million), due to the below average 2009 and 2008 brood year escapements for most stocks. Conversely, there is a one out of four chance the return will be above the cycle average if Fraser Sockeye productivity falls at the high end of past observations. If low productivity conditions resume, based on the sensitivity analysis forecast, returns could range from 523,000 to 5,419,000 at the 10% to 90% probability levels. In this scenario, the entire distribution falls below the cycle average.

For Fraser Pink Salmon, there is a one in ten chance (10% probability) the return will be at or below 4,794,000 and a nine in ten chance (90% probability) it will be at or below 17,111,000. The mid-point of this distribution (50% probability level) is 8,926,000 (Table 1). The Fraser Pink forecast is highly uncertain, given the methods used to estimate returns have changed over time, and these changes have not been calibrated between years.

INDIVIDUAL STOCK FORECASTS

Early Stuart Run (Takla-Trembleur-Early Stuart CU)

The 2009 brood year is the dominant cycle for the Early Stuart stock. However, the 2009 escapement of 21,900 EFS for Early Stuart was the second lowest escapement observed on this cycle, falling well below the cycle average of 114,400 EFS (brood years 1949-2005) (Table 1, column C). Juvenile fry data have not be collected in this system since the 2009 brood year (2010 data collection year), due to an ongoing safety issue at this site.

Physical conditions (water levels and temperature) on the spawning grounds were within an acceptable range for successful spawning during the 2009 Early Stuart spawning season, despite hot and dry weather. Sockeye were reported to be in good condition, with no evidence of migration difficulties. Spawning success averaged 95% for the Early Stuart populations, falling higher than the long-term average (89%).

Average four year old productivity (age-4 R/EFS) for Early Stuart Sockeye declined from a peak of 24.5 R/EFS in the mid-1960 brood years (four year consecutive peak average) to one of the lowest productivities on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figures 3 & 4). Preliminary return estimates for 2010 to 2012 indicate that the long-term performance forecast is more appropriate (falls near the mid-point of the forecast distribution) (Figure 4) than the recent model performance forecast for this stock.

For Early Stuart, the top ranked models (based on the average rank across all four performance measures: MRE, MAE, MPE, RMSE) are the Ricker (Ei) (tied first), Ricker (Pi) (tied first), Ricker (tied third), and Ricker (PDO) (tied third) (Table 5). For each individual performance measure, these models each ranked within the top 50% (10 out of 20) of all models compared for this stock (see Table 5 in MacDonald & Grant 2012). Forecasts produced by the top ranked models were similar, with the smallest forecast (Ricker) deviating by 26% from the largest forecast (Ricker (Ei)) (percent difference between smallest and largest forecasts at the 50%-median probability level, calculated as a percentage of the largest forecast) (Table 5). The Ricker (Ei) model was used for the 2013 Early Stuart forecast, as it ranked first on average across performance measures, and it outperformed the other first-ranked model (Ricker (Pi)) on two of the four individual performance measures (and tied on one) (Table 5 in MacDonald & Grant 2012). Given the assumptions underlying the Ricker (Ei) model, there is a one in four chance (25% probability) the Early Stuart Sockeye return will be below 137,000 (5.5 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 331,000 (14.2 age-4 R/EFS) in 2013. The median (one in two chance: 50% probability) forecast of 211,000 (8.9 age-4 R/EFS) is below the average return on this cycle (792,000) (Tables 1 & 2; Figure 3). The five year old component of the 2013 return is expected to contribute 7% of the total forecasted return (at the 50% probability level) (Table 3).

**Note: For the remaining stock sections the following were consistently applied: top ranked model forecasts were compared according to the percent difference between smallest and largest forecasts at the 50%-median probability level (calculated as a percentage of the largest forecast); unless otherwise noted, in all subsequent sections the top three models each ranked within the top half of all models compared for the stock on all four performance measures; also, comparisons of ranks on individual performance measures refer only to the top three models.*

Early Summer Run

The Early Summer Run consists of a number of less abundant stocks relative to the more abundant Summer and Late Run stock groups. Seven stocks in this timing group are forecast using the standard suite of forecast models: Bowron, Fennell, Gates, Nadina, Pitt, Scotch, and Seymour (Table 1). In the past year, a decision was made by the Fraser Panel of the Pacific Salmon Treaty process to move Raft and North Thompson miscellaneous stocks into the Summer Run timing group, due to changes in timing of these stocks. Escapement in the 2009

brood year for all Early Summer stocks combined was 34,600 EFS (largely attributed to the average four year old EFS for Pitt), which is similar to the long term cycle average of 31,300 EFS.

Three of the seven Early Summer stocks had 2009 brood year escapements (EFS) that were below their cycle averages (Bowron, Fennell & Nadina), while the other four were close to average (Pitt, Gates, Scotch & Seymour). Pitt Sockeye, which are comprised of predominantly five year old recruits, had a below average brood year escapement for the 2008 brood year. The total 2009 brood year EFS for the Early Summer Run, including the miscellaneous stocks (miscellaneous South Thompson, Dolly Varden/Chilliwack Lake, and Nahatlatch) was 38,900. The 2009 brood year EFS for each Early Summer Run stock (except Pitt) was below 6,000.

Water levels in several areas of the Early Summer Run aggregate spawning grounds were at or close to record lows in 2009, due to hot and dry conditions. Low water reportedly limited or restricted fish access in several systems within the South Thompson systems. Water temperatures, however, were within an acceptable range for spawning in most systems, and Sockeye were reported to be in good condition upon their arrival. Warm water was reported in the Nadina system, and early arrivals experienced high mortality. Spawning success in 2009 was high (95%) for the Early Summer Runs compared to the long-term average for these stocks (89%). Upper Pitt Sockeye experienced the lowest spawning success on record for this system in 2008 (61%), the brood year for the predominant five year old age class for this stock, which was well below the cycle average (89%).

Preliminary return estimates for the 2010 to 2012 Early Summer Run aggregate indicate that long-term model performance forecasts are more appropriate (returns fall near the mid-point of this forecast distribution) than recent model performance forecasts for these stocks (Figure 4). However, the recent return estimates are not finalized on a stock-specific basis, and historical data show considerable variability in productivity amongst stocks. Therefore, readers interested in specific stocks may find the forecasts in both Table 1 and in Appendix Table A1 (based on recent model performance) helpful in anticipating the range of potential returns for stocks within the aggregate.

Bowron (Bowron-ES CU)

The 2009 brood year escapement for Bowron (1,000 EFS) was one third of the long-term cycle average (1949-2005 average: 2,900 EFS) (Table 1, column C).

Average four year old productivity (R/EFS) for Bowron Sockeye declined from a peak of 20.4 R/EFS in the mid-1960 brood years (four year average at peak) to one of the lowest productivities on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3).

For Bowron, the top ranked models are MRS, Ricker (Pi), and Ricker (Ei) (Table 5). Forecasts produced by the top ranked models were similar, varying by 19% (Table 5). The MRS model was used for the 2013 Bowron forecast, as it ranked first on average across performance measures, and it ranked the same or better than other top ranked models on each individual performance measure (Table 5 in MacDonald & Grant 2012). Given the assumptions underlying the MRS model, there is a one in four chance (25% probability) the Bowron Sockeye return will be below 3,000 (3.2 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 14,000 (12.8 age-4 R/EFS) in 2013. The median (one in two chance: 50% probability) forecast of 7,000 (6.4 age-4 R/EFS) is well below the average return on this cycle (24,000) (Tables 1 & 2; Figure 3). The five year old component of the 2013 return is expected to contribute 7% of the total forecasted return (at the 50% probability level) (Table 3).

Fennell (North Barriere-ES (*de novo*) CU)

The 2009 brood year escapement for Fennell (700 EFS) was less than half of the cycle average (2,000 EFS) from 1969 to 2005 (Table 1, column C).

Average four year old productivity (R/EFS) for Fennell Sockeye declined from a peak of 53.5 R/EFS in the early 1970 brood years (four year average at peak) to one of the lowest productivities on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3).

For Fennell, the top ranked models are the power, RAC, and Ricker models (Table 5). Forecasts produced by the top ranked models were similar, varying by 29% (Table 5). The power model was used for the 2013 Fennell forecast, as it ranked first on average across performance measures, and, with the exception of the RAC model, it ranked as well as, or better than other top ranked models on each individual performance measure except MAE (ranked third) (Table 5 in MacDonald & Grant 2012). Given the assumptions underlying the power model, there is a one in four chance (25% probability) the Fennell Sockeye return will be below 5,000 (5.2 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 15,000 (18.4 age-4 R/EFS) in 2013. The median (one in two chance: 50% probability) forecast of 9,000 (9.6 age-4 R/EFS) is below the average return on this cycle (12,000) (Tables 1 & 2; Figure 3). The five year old component of the 2013 return is expected to contribute 22% of the total forecasted return (at the 50% probability level) (Table 3).

Gates (Anderson-Seton-ES CU)

The 2009 brood year escapement for Gates (5,300 EFS) fell into the average range, though it was larger than the cycle average (3,900 EFS) from 1969 to 2005 (Table 1, column C). Gates juvenile data is not used in the forecast process due to inconsistencies in data collection methods over time.

Average four year old productivity (R/EFS) for Gates Sockeye declined steadily from a peak of 41.0 R/EFS in the early-1970 brood years (four year average at peak) to one of the lowest productivities on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3).

For Gates, the top ranked models are the RAC, R2C, Larkin (tied third) and MRS (tied third) models (Table 5). For each individual performance measure, the RAC, Larkin and MRS models each ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5 in MacDonald & Grant 2012); the R2C model, however, did not. Forecasts produced by the RAC, Larkin and MRS models differed, varying by 43% (Table 5). The RAC non-parametric model produced the lowest forecast compared to those produced by the Larkin and MRS models, as the RAC model does not include EFS as a predictor variable. Although the brood year EFS fell within the average range of escapements, since the RAC model forecast varied quite a bit from the Larkin and MRS forecasts, which include EFS as a predictor variable, the Larkin biological model was used to generate the 2013 forecast for this stock. Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Gates Sockeye return will be below 37,000 (6.2 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 115,000 (21.2 age-4 R/EFS) in 2013. The median (one in two chance: 50% probability) forecast of 67,000 (12.2 age-4 R/EFS) is larger than the average return on this cycle (40,000) (Tables 1 & 2; Figure 3). The five year old component of the 2013 return is expected to contribute 4% of the total forecasted return (at the 50% probability level) (Table 3).

Nadina (Nadina-Francois-ES CU)

The 2009 brood year escapement for Nadina (3,700 EFS) was less than half the cycle average (8,600 EFS) from 1973-2005 (Table 1, column C). Spawning success for this stock was low in the 2009 brood year. Juvenile fry data, used as an index of juvenile abundance, indicate that

early freshwater survival in the 2009 brood year (1,270 fry/EFS) was average for this cycle (1,000 fry/EFS) and juvenile abundance (5.46 million fry) was well below the cycle average (1973-2005 average: 9.4 million fry).

Average four year old productivity (R/EFS) for Nadina Sockeye declined from a peak of 13.5 R/EFS in the mid-1970 brood years (four year average at peak) to one of the lowest productivities on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3).

For Nadina, the top ranked models are the MRJ, Ricker (FrD-peak) (tied second), and power (juv) (FrD-peak) (tied second) (Table 5). These three models each ranked within the top 50% (17 out of 33 models) of all models compared for this stock on three of the four individual performance measures. However, all three models each ranked poorly (ranked ≥ 19 out of 33) on the MRE performance measure (Table 5 in MacDonald & Grant 2012). Of the 33 models explored for Nadina, none ranked in the top 50% across all performance measures (all models either ranked well on MRE and poorly on all other performance measures, or vice versa). Therefore, the MRE performance measure was not used to inform model selection. Forecasts produced by the top ranked models were similar, varying by 18% (Table 5). The MRJ model was used for the 2013 Nadina forecast, as it ranked first on average across performance measures, and it ranked first on each individual performance measure except MRE (ranked 28th) (Table 5 in MacDonald & Grant 2012). Given the assumptions underlying the MRJ model, there is a one in four chance (25% probability) the Nadina Sockeye return will be below 20,000 (3.6 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 95,000 (16.8 age-4 R/EFS) in 2013. The median (one in two chance: 50% probability) forecast of 44,000 (7.8 age-4 R/EFS) is half of the average return on this cycle (72,000) (Tables 1 & 2; Figure 3). The five year old component of the 2013 return is expected to contribute 34% of the total forecasted return (at the 50% probability level) (Table 3).

Pitt (Pitt-ES CU)

Annual returns for Pitt consist of a greater proportion of five year old recruits (~70%) than other Fraser Sockeye stocks. Due to the greater proportion of five year old recruits (~70%) relative to four year old recruits for Pitt, brood year escapements were compared to the time-series average, rather than the cycle average. The brood year escapement for Pitt in 2008 (for five year old recruits returning in 2013: 5,400 EFS) was well below the average escapement from 1948-2008 (13,700 EFS). The 2009 escapement (four year old recruits returning in 2013: 18,100 EFS) was greater than the average, though it still fell within the average range (average ± 0.5 standard deviations) (13,700 EFS) (Table 1, columns D & C).

Average five year old productivity (R/EFS) for Pitt Sockeye has been variable throughout the time series, with a second peak of 13.3 five year old R/EFS (four year average at peak) occurring in the early 1990's. Subsequently, productivity declined for this stock, culminating in one of the lowest productivities on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3).

For Pitt, the top ranked models are the Larkin, TSA and Ricker (PDO) models (Table 5). For each individual performance measure, only the Larkin model ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5 in MacDonald & Grant 2012). Forecasts produced by the top ranked models were quite different, varying by 79% from the largest forecast (TSA) (percent difference between smallest and largest forecasts at the 50%-median probability level, calculated as a percentage of the largest forecast) (Table 5). This large difference is attributed to the non-parametric TSA model (time series average returns across all cycles)), which does not use brood year EFS to forecast returns, and therefore produced a much larger forecast than the biological models. The Larkin model produced a smaller forecast than the Ricker (PDO) model, due to the higher brood year escapements in the three years prior to the four and five year old brood years. The top performing Larkin model was used to generate

this forecast (Table 5). Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Pitt Sockeye return will be below 9,000 (0.2 age-5 R/EFS) and a three in four chance (75% probability) the return will be below 28,000 (0.7 age-5 R/EFS) in 2013. The median (one in two chance: 50% probability) forecast of 15,000 (0.4 age-5 R/EFS) is only 20% of the average return (74,000) (Tables 1 & 2; Figure 3). Although five year olds typically dominate total Pitt Sockeye returns, due to the extremely low 2008 brood year escapement, the five year old component of the 2013 return is expected to contribute only 13% of the total forecasted return (at the 50% probability level) (Table 3).

Scotch (a component of the Shuswap-ES CU)

The 2009 brood year escapement for Scotch (2,700 EFS) was very close to the cycle average (3,000 EFS) (Table 1, column C) from 1981-2005. The 2009 brood year is the last of three off-cycle years for Scotch, with the dominant cycle occurring on the 2010 cycle line. Scotch Creek became dominant on this cycle in 1982, due to past hatchery transplants on this cycle from the Seymour River, and now coincides with the Adams River dominant cycle.

Average four year old productivity (R/EFS) for Scotch Sockeye declined from a peak of 21.5 R/EFS in the early 1980 brood years (four year average at peak) to one of the lowest productivities on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3).

For Scotch, the top ranked models are the Larkin, Ricker and RS1 (Table 5). For each individual performance measure, the Larkin and Ricker models each ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5 in MacDonald & Grant 2012). Forecasts produced by the Larkin and Ricker models were quite different, varying by 89% (Table 5). The Larkin model forecast is much smaller than the Ricker model, due to the Larkin model's consideration of delayed-density dependent interactions between the 2008 brood year escapement, and the relatively high Scotch Creek escapements in previous years (Table 5). However, given that delayed-density dependence should occur in the freshwater lake rearing environment, and Scotch Sockeye share this rearing environment with many other stocks that occupy the Shuswap Lake complex (including the Seymour and Adams stocks), it is unlikely that the small Scotch Creek Sockeye population would drive this effect, as assumed by the Larkin model fit. Instead, it is more likely the dominant Adams Late Run (Late Shuswap) population drives delayed-density dependence of all Sockeye stocks rearing in Shuswap Lake. For comparison, the Early Summer timed Seymour stock, which also rears in Shuswap Lake as fry, does not exhibit delay-density dependence for the 2013 forecast year, as evidenced by the lack of difference between Larkin and Ricker model forecasts for this stock (Table 5). Further, the stock-recruitment time series for Scotch is relatively short (1980 to 2005 brood year), which may contribute to challenges in estimating the parameters of the Larkin model. Therefore, for all these reasons, the Ricker model was used to generate this stock's 2013 forecast. Given the assumptions underlying the Ricker model, there is a one in four chance (25% probability) the Scotch Sockeye return will be below 8,000 (2.8 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 39,000 (14.6 age-4 R/EFS) in 2013. The median (one in two chance: 50% probability) forecast of 17,000 (6.4 age-4 R/EFS) is low compared to the average return on this cycle (25,000) (Tables 1 & 2; Figure 3). The five year old component of the 2013 return is expected to contribute 0% of the total forecasted return (at the 50% probability level) (Table 3).

Seymour (a component of the Shuswap-ES CU)

The 2009 brood year escapement for Seymour (3,100 EFS) was almost identical to the cycle average (3,200 EFS) from 1949-2005 (Table 1, column C). The 2009 brood year is the second off-cycle year for Seymour, with the dominant cycle occurring on the 2010 brood year cycle line.

Average four year old productivity (R/EFS) for Seymour Sockeye declined steadily from a peak of 29.2 R/EFS at the start of the time series in the 1970's (four year average at peak) to one of the lowest productivities on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3).

For Seymour, the top ranked models are the Ricker-cyc, R1C (tied second) and Larkin (tied second) (Table 5). For each individual performance measure, the Ricker-cyc and R1C models each ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5 in MacDonald & Grant 2012). Forecasts produced by these two models were quite different, varying by 61% (Table 6). This was attributed to the extremely low forecast produced by the second ranked R1C model, which uses the low return of the previous cycle as the forecast, and does not include the EFS as a predictor variable. The Ricker-cyc model was used for the 2013 Seymour forecast, as it ranked first on average across performance measures, and it outperformed the R1C model on three of four performance measures (ranked second on MRE) (Table 5 in MacDonald & Grant 2012). Given the assumptions underlying the Ricker-cyc model, there is a one in four chance (25% probability) the Seymour Sockeye return will be below 12,000 (3.7 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 36,000 (11.7 age-4 R/EFS) in 2013. The median (one in two chance: 50% probability) forecast of 21,000 (6.5 age-4 R/EFS) is close to the average return on this cycle (27,000) (Tables 1 & 2; Figure 3). The five year old component of the 2013 return is expected to contribute 3% of the total forecasted return (at the 50% probability level) (Table 3).

Summer Run

The Summer Run consists of six stocks: Chilko, Late Stuart, Quesnel, Stellako and the recently added Raft and Harrison (Table 1); Raft and Harrison were added to this Run timing group for the 2013 forecast due to changes in their run timing, which now coincides with the Summer Run. Escapement in the 2009 brood year for these six stocks combined (375,867 EFS) was well below the long-term cycle average (925,000 EFS). Chilko (43%) contributed the most to the Summer Run EFS, followed by Quesnel (33%) and Late Stuart (9%). Physical conditions on the Summer Run aggregate spawning grounds were extremely hot and dry in 2009. Fish access to several streams was reportedly limited by very low water levels in the Quesnel and Mid-Fraser areas, while high water levels were experienced in other areas (Chilko). Low water reportedly limited or restricted fish access in several systems within the North Thompson systems. However, water temperatures remained within an acceptable range in most streams, and Sockeye appeared to be in good condition on the spawning grounds (excluding Harrison). The average spawning success for the group (99%) was well above the historical average (90%). Elevated levels of en-route and pre-spawning mortality were observed in the Harrison-Lillooet region.

Preliminary return estimates for the 2010 to 2012 Summer Run aggregate indicate that long-term model performance forecasts are more appropriate (returns fall near the mid-point of this forecast distribution) than model performance forecasts for these stocks (Figure 4). However, the recent return estimates are not finalized on a stock-specific basis, and historical data show considerable variability in productivity amongst stocks. Therefore, readers interested in specific stocks may find the forecasts in both Table 1 and in Appendix Table A1 (based on recent model performance) helpful in anticipating the range of potential returns for stocks within the aggregate.

Chilko (Chilko-S & Chilko-ES CU)

The 2009 brood year escapement for Chilko (127,400 EFS) was very similar to the cycle average (124,600 EFS) from 1949-2005. Chilko freshwater survival for the 2009 brood year (269 smolts/EFS) was over double the cycle average (117 smolts/EFS) (Figure 2 A). Juvenile (smolt) abundance for the 2009 brood year (34.4 million age-1 smolts) was above the long-term

cycle average (brood years 1953-2005: 14.5 million age-1 smolts) (Table 1, column C). Smolt abundance in the previous (2008) brood year, for the five year old Sockeye returning in 2013 (11.8 million one year old (sub2) smolts), was much lower than the long-term average on that cycle (1952-2004 average: 21.7 million one year old smolts). Smolt body sizes in the 2008 (91.9 mm) and 2009 (87.3 mm) brood years were both above the long-term (brood years 1953-2009) average (83.3 mm).

Average four year old post-smolt (mostly marine) survival (R/smolt) for Chilko Sockeye declined steadily from a peak of 18% in the late-1980 brood years (four year average at peak) to one of the lowest post-smolt survivals on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 2 B & Figure 3).

For Chilko, the top ranked models are the power (juv) (Pi) (tied first), Larkin (tied first) and Power (juv) models (Table 5). For each individual performance measure, none of these models ranked within the top 50% (17 out of 33) of all models compared for this stock (Table 5 in MacDonald & Grant 2012). All three models ranked poorly on MRE, therefore the MRE performance measure was not used to inform model selection. Forecasts produced by the top ranked models were similar, varying by 27% (Table 5). The Larkin model generated the lowest forecast, as it considers delayed-density dependent interactions between previous escapements, whereas the two other top ranked models use smolt abundance and freshwater survival as predictor variables, both of which were well above average (Table 5). The power (juv) (Pi) model was used to generate the forecast for this stock. Given the assumptions underlying the power (juv) (Pi) model, there is a one in four chance (25% probability) the Chilko Sockeye return will be below 1,147,000 (3% age-4 marine survival) and a three in four chance (75% probability) the return will be below 2,929,000 (8% age-4 marine survival) in 2013. The median (one in two chance: 50% probability) forecast of 1,829,000 (5% age-4 marine survival) is well above the average return on this cycle (824,000) (Tables 1 & 2; Figure 3). The five year old component of the 2013 return is expected to contribute 7% of the total forecasted return (at the 50% probability level) (Table 3).

Late Stuart (Takla-Trembleur-Stuart-S CU)

The 2009 brood year is dominant cycle for Late Stuart. However, the 2009 brood year escapement (43,300 EFS) was less than one fifth the cycle average (239,500 EFS) from 1949-2005 (Table 1, column C). Spawning success in the Late Stuart system was 99% in 2009, above the long-term average of 92%.

Average four year old productivity (R/EFS) for Late Stuart Sockeye declined from a peak of 57.2 R/EFS in the early 1950's, with subsequent, lower peaks in the late 1960's and mid-1980's to one of the lowest productivities on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3).

For Late Stuart, the top ranked models are the R1C, R2C, and power models (Table 5) (Note: there is an error in the Ricker model performance measures in Table 5 of MacDonald & Grant 2012). The Ricker model is not actually tied for the third ranked model. Performance measure values for Ricker are MRE: -0.033, MAE: 0.521, MPE: -1.673, RMSE: 0.9. For each individual performance measure, the R1C and R2C models ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5 in MacDonald & Grant 2012). Forecasts produced by the three top ranked models were quite different, varying by 60% (Table 5). The non-parametric models R1C & R2C produced the lowest forecasts since they include the poor productivity, and therefore, poor returns of the 2005 brood year (R1C is particularly low since it only includes the 2009 return year in its estimation, which corresponds largely to the 2005 brood year). The top ranked biological model (power) was used to generate the 2013 forecast, despite its relatively poor performance on the MRE performance measure, as it includes the below average brood year escapement as a predictor variable and does not emphasize the recent low productivity period (Table 5). Given the assumptions underlying the power model, there is a one in four

chance (25% probability) the Late Stuart Sockeye return will be below 151,000 (2.6 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 686,000 (13.8 age-4 R/EFS) in 2013. The median (one in two chance: 50% probability) forecast of 333,000 (6.3 age-4 R/EFS) is well below the average return on this cycle 1.65 million (Tables 1 & 2; Figure 3). The five year old component of the 2013 return is expected to contribute 11% of the total forecasted return (at the 50% probability level) (Table 3).

Quesnel (Quesnel-S CU)

The 2009 brood year is the dominant cycle for Quesnel. However, escapement in 2009 (82,800 EFS) was one sixth the cycle average (508,200 EFS) from 1949-2005 (Table 1, column C), and was the lowest escapement on this cycle since 1969. Freshwater productivity in the brood year (165 fall fry/EFS) was above the cycle average (1977-2009 brood years: 106 fall fry/EFS), and brood year fall fry body sizes were also greater (4.9 g) than the cycle average (3.6 g). This is the highest freshwater productivity observed for this stock on its dominant cycle since 1981, when this stock's abundance increased significantly on both the dominant and subdominant cycles. Average freshwater productivity on Quesnel's dominant cycle from 1985 to 2005 was 50 fall fry/EFS, compared to the average productivity on the two cycles prior to this period (1977 & 1981) of 256 fall fry/EFS. This is the one stock where there is evidence that delayed-density dependence may have explained the post-1990 declines in productivity (Peterman & Dorner 2012).

Average four year old productivity (R/EFS) for Quesnel Sockeye declined from a peak of 18.1 R/EFS in the late-1960's to one of the lowest productivities on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3).

For Quesnel, the top ranked models are the R1C, R2C and Ricker-cyc (Table 5). For each individual performance measure, each of these models ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5 in MacDonald & Grant 2012). Forecasts produced by the top ranked models were quite different, varying by 89% (Table 5). The non-parametric model R1C produced the lowest forecast since it includes the poor productivity, and therefore, poor returns of the 2005 brood year. The top ranked biological model (Ricker-cyc) was used to generate the 2013 forecast, as it includes the below average brood year escapement as a predictor variable and does not emphasize the recent low 2005 brood year productivity (Table 5). Given the assumptions underlying the Ricker-cyc model, there is a one in four chance (25% probability) the Quesnel Sockeye return will be below 596,000 (7.2 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 2,445,000 (29.5 age-4 R/EFS) in 2013. The median (one in two chance: 50% probability) forecast of 1,218,000 (14.7 age-4 R/EFS) is below the average return on this cycle (3.96 million) (Tables 1 & 2; Figure 3). The five year old component of the 2012 return is expected to contribute 0.1% of the total forecasted return (at the 50% probability level) (Table 3).

Additional models were analyzed for Quesnel to investigate the effect of alternative predictor variables and model forms on this stock's forecast (Table 5). The extra analysis was conducted for this stock in particular as Quesnel contributes a higher proportion to the total forecast (Table 1) and appears to have exhibited interactions between cycle lines (delayed-density dependence) in recent years (Peterman & Dorner 2012). Given the higher early freshwater survival of Quesnel in the 2009 brood year, a model that uses juvenile abundance as a predictor variable was compared to top ranked models that used the EFS predictor variable (i.e. Ricker-cyc and lower ranked Ricker biological models) (Table 5). The four year old forecasts only were compared for these three models, given that fry data were only available for the 2009 (four year old) brood year, and not the 2008 (five year old) brood year. The forecast produced for the power-fry model was smaller than those produced by the Ricker-cyc or Ricker models that use EFS as a predictor variable, despite high freshwater survival in the 2009 brood year (Table 5). This result contradicts the expectation that using fry as a predictor variable would produce a

higher forecast than using EFS , and is likely attributed to the considerable gaps in the fry time series, and higher uncertainty in the fry estimates. The Larkin model (ranked 5th) was also compared to the top ranked Ricker-cyc model (ranked 3rd) and lower ranked Ricker model (ranked 16th), since this model considers delayed-density dependence observed for this stock in recent years. Both the Larkin (ranked 5th) and Ricker-cyc 50% probability forecasts were greater than 1 million, versus the standard Ricker model forecast of ~850,000 (Table 5). Therefore, consideration of either cycle line interactions or cycle line specific stock-recruitment relationships increased the forecast over biological models that do not incorporate cyclicity.

Stellako (Francois-Fraser-S CU)

The 2009 brood year escapement for Stellako (15,800 EFS) was below the cycle average (29,900 EFS) from 1949-2005 (Table 1, column C).

Average four year old productivity (R/EFS) for Stellako Sockeye declined from a peak of 15.1 R/EFS in the early 1970's to one of the lowest productivities on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3).

For Stellako, the top ranked models are the R2C, Larkin and Ricker (Ei) (Table 5). For each individual performance measure, only the R2C model ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5 in MacDonald & Grant 2012). The Larkin and Ricker (Ei) models ranked, respectively, 13th and 11th on the MRE performance measure (Table 5 in MacDonald & Grant 2012). Forecasts produced by the top ranked models differed, varying by 55% (Table 5). Given the below average brood year escapement for Stellako, the top ranked biological model (Larkin) was used to generate the 2013 forecast (Table 5). Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Stellako Sockeye return will be below 131,000 (3.5 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 291,000 (10.0 age-4 R/EFS) in 2013. The median (one in two chance: 50% probability) forecast of 192,000 (5.7 age-4 R/EFS) is below the average return on this cycle (245,000) (Tables 1 & 2; Figure 3). The five year old component of the 2013 return is expected to contribute 53% of the total forecasted return (at the 50% probability level) (Table 3). The Larkin forecast considers delayed-density dependence, and therefore produces a smaller forecast than the Ricker model, due to above average escapements in the previous brood year (2008).

Raft (Kamloops-ES CU): Recently Moved From Early Summer Run Group

The 2009 brood year escapement for Raft (6,000 EFS) was close to the cycle average (4,000 EFS) from 1949-2005 (Table 1, column C).

This stock has not exhibited any systematic productivity trends over time (Grant et al. 2011; Peterman & Dorner 2012). Average four year old productivity (R/EFS) for Raft Sockeye has been variable over the time series, with the largest peak of 13.6 R/EFS in the late-1960's/early-1970 brood years (four year average at peak). However, similar to other Fraser Sockeye stocks, Raft exhibited the lowest productivity on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, column E; Figure 3).

For Raft, the top ranked models are Ricker (PDO), Ricker-cyc (tied second) and power (tied second) (Table 5). For each individual performance measure, only the Ricker (PDO) model ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5 in MacDonald & Grant 2012). Forecasts produced by the three top ranked models were similar, varying by 28% (Table 5). The Ricker (PDO) model was used for the 2013 Raft forecast, as it ranked first on average across performance measures, and it ranked highest on each individual performance measure except RMSE (ranked fourth) (Table 5 in MacDonald & Grant 2012). Given the assumptions underlying the Ricker (PDO) model, there is a one in four chance (25% probability) the Raft Sockeye return will be below 32,000 (3.2 age-4 R/EFS) and a three in four

chance (75% probability) the return will be below 81,000 (10.6 age-4 R/EFS) in 2013. The median (one in two chance: 50% probability) forecast of 51,000 (5.9 age-4 R/EFS) is almost double the average return on this cycle (28,000) (Tables 1 & 2; Figure 3). The five year old proportion of the 2013 return is expected to contribute 31% of the total forecasted return (at the 50% probability level) (Table 3), similar to the recent average age five contribution (1980-2005 average age-5 proportions of total returns: 36%). The Ricker (PDO) produced a higher forecast than the Ricker-cyc and Power models, given the cooler water temperature during the smolt outmigration years.

Harrison (Harrison-River Type CU): Recently Moved from Late Run Group

Harrison Sockeye have a unique life history and age structure compared to other Fraser Sockeye stocks. Harrison Sockeye migrate to the ocean shortly after gravel emergence (most Fraser Sockeye rear in lakes for one to two years after gravel emergence prior to their ocean migration). After two to three years in the ocean, Harrison Sockeye return, predominantly as three or four year old fish (most Fraser Sockeye return as four and five year old fish). Proportions of three and four year old Harrison recruits vary considerably inter-annually, with four year old proportions ranging from 10% to 90% of total recruits (Grant et al. 2010). Odd brood years, on average, produce a higher proportion of four year old recruits, and even years produce a higher proportion of three year old recruits (Grant et al. 2010). The extreme annual variation in age proportions for Harrison Sockeye increases the level of forecast uncertainty for this stock.

The 2009 brood year escapement (four year old recruits in 2013) for Harrison Sockeye (100,600 EFS) was the third largest on record, falling well above the long-term average (12,100 EFS). The 2010 brood year escapement (400,000 EFS) (three year old recruits in 2013) was the largest on record, and also fell well above the long-term average (12,100 EFS). Harrison Sockeye escapements are compared to the entire time series instead of the cycle average, since Harrison have variable four year old returns and are, therefore, not cyclic (Table 1, columns C & D). Harrison Sockeye spawning success was identical in the 2009 (age 4 (4_1) returns in 2013) and 2010 (three year old returns (3_1) in 2013) brood years at 94%.

Unlike most other Fraser Sockeye stocks, average productivity (R/EFS) for Harrison Sockeye increased to a maximum of 33.8 R/EFS in mid-1990's (Table 2, columns B to E). Similar to other stocks, however, the 2005 brood year productivity (i.e. 2009 four year old return year) (Table 2, column E) was the lowest on record. Given the unique age structure of Harrison, despite poor productivity in the 2005 brood year, returns were above average in 2009 and 2010, and have been average in subsequent years (Figure 4).

Harrison Sockeye have been extremely challenging to forecast in recent years due to the large increases in escapements and productivity (Grant et al. 2010; Grant et al. 2011), and the inter-annual variation in this stock's four year old proportions (see first paragraph of this Harrison forecast section). Historically (up to the year 2000), Harrison Sockeye escapements averaged 6,500 EFS, while productivity remained around 15 R/EFS. In recent years, (post-2000), escapements have averaged 100,000 EFS, and productivity has been double the average at 32 R/EFS; though the most recent 2006 and 2007 brood year productivity estimates are similar to the long-term average (13.6 R/EFS). The extremely large brood year escapements in both 2009 and 2010 greatly increase forecast uncertainty for this stock. The 2005 brood year has the only paired escapement and recruitment data that fall within this range of high escapements to inform the fit of biological models. That large 2005 brood year escapement (212,000 EFS) resulted in a low total recruitment of 17,000 Sockeye, indicating either density dependence or low productivity in this brood year. Since the brood year escapements for 2009 and 2010 fell well out of the range of most previously observed Harrison Sockeye escapements (apart from the 2005 brood year), with such limited data there is extreme uncertainty associated with the fit of biological models and their associated predictions. Non-parametric model forecasts are also

extremely uncertain, as they are unable to take into account potential density dependence at high spawner abundances. None of these additional sources of uncertainty are captured in the forecast probability distributions. The difference in odd versus even year age proportions is accounted for in the Harrison forecast models (MacDonald & Grant 2012). However, age proportions can vary considerably, creating greater uncertainty in Harrison forecasts.

For Harrison, the top ranked models are the Ricker (Ei), Ricker (FrD-peak) (tied second) and R2C (tied second) (Table 5). Each of these models ranked within the top 50% (10 out of 20) of all models compared for this stock on all but one performance measure (Table 5 in MacDonald & Grant 2012). Forecasts produced by the top ranked models were quite different, varying by 81% (Table 5). This difference is attributed to the R2C model, which predicted high returns based on the previous two cycle years (2005 and 2009), in which returns were in the 400,000 range. The Ricker (Ei) model was chosen to produce the 2013 forecast as it ranked high on all performance measures, and was the top ranked model overall. Given the assumptions underlying the Ricker (Ei) model, there is a one in four chance (25% probability) the Harrison Sockeye return will be below 31,000 and a three in four chance (75% probability) the return will be below 205,000 in 2013. The median (one in two chance: 50% probability) forecast of 82,000 is larger than the average return across all cycles (60,000) (Tables 1 & 2; Figure 3). The three year old component of the 2013 return is expected to contribute 0% of the total forecasted return (at the 50% probability level). Despite the high brood year escapement for three year olds returning in 2013 (2010 brood year EFS of 400,000), the expected three year old contribution is negligible largely due to density dependence at exceptionally high spawner abundances, as predicted by the Ricker model, and to a lesser extent, due to the lower historical proportion of three year olds on even cycles (0.46).

Caution: the presented forecast for Harrison Sockeye is associated with **extreme** uncertainty. The amount of uncertainty represented by this forecast distribution does not include the recent changes in this system's productivity and escapements. Additionally, the model is forecasting outside the range of previously observed data. It is entirely possible that the actual return will fall outside this forecast distribution, either at the low or high end of the distribution. Additional years of data at these high escapements are required to increase the certainty of the Harrison Sockeye forecasts.

Late Run

The Late Run consists of five stocks: Cultus, Late Shuswap, Portage, Weaver, and Birkenhead (Table 1); Harrison was recently moved to the Summer Run timing group due to changes in the run timing of this stock. The total escapement for the Late Run aggregate in 2009 was the second largest on record for this cycle, with 72,100 EFS (excluding Cultus). This escapement was above the cycle average of 48,000 EFS (Table 1). The miscellaneous Late Run stocks (e.g. Harrison Lake rearing stocks) combined brood year EFS was 3,700 (Table 1). Early arrival on the spawning grounds was not observed for the Late Run in 2009, with the exception of Cultus. However, elevated levels of en-route and pre-spawning mortality were observed in the Harrison-Lillooet region. Physical conditions on the Late Run aggregate spawning grounds were within an acceptable range, with the exception of the South Thompson, where low water reportedly limited access to smaller streams. Spawning success was variable across the Late Run aggregate stocks in the 2009 brood year, ranging from 27% to 97% in the Lower Fraser; 44-100% in the Harrison-Lillooet; 87-99% in the South Thompson; and 87% in the Seton-Anderson system. Overall, average spawner success was 93% for the Late Run aggregate.

Preliminary return estimates for the 2010 to 2012 Late Run aggregate indicate that long-term performance forecasts are more appropriate (returns fall near the mid-point of this forecast distribution) than recent model performance forecasts for these stocks (Figure 4). However, the recent return estimates are not finalized on a stock-specific basis, and historical data show considerable variability in productivity amongst stocks. Therefore, readers interested in specific

stocks may find the forecasts in both Table 1 and in Appendix Table A1 (based on recent model performance) helpful in anticipating the range of potential returns for stocks within the aggregate.

Cultus (Cultus-L CU)

Total Cultus Sockeye escapement (counted through the Sweltzer Creek enumeration fence) in the 2009 brood year (1,700 Sockeye: jacks plus adults) was the largest on this cycle in three decades. Jacks comprised 50% of this escapement. In 2009, 84% percent of the adult Cultus Sockeye that returned to the enumeration fence were adipose fin clipped (hatchery origin). Cultus Sockeye have been exhibiting early migration to the Cultus fence since the mid-1990's, which continued in 2009. Few female Sockeye carcasses were recovered in the 2009 brood year (22), due to the low abundance in the system, and the inherent difficulties in recovering lake spawners, therefore the estimate of spawner success (35%) is highly uncertain. Hatchery supplementation of fry into Cultus Lake and smolts into Sweltzer Creek (downstream of the enumeration fence) has increased the number of outmigrating smolts since the hatchery program commenced in the 2000 brood year. The smolt abundance in the 2009 brood year (174,000), of which 67% were hatchery origin, was less than the long-term cycle average (286,000) (Table 1). At the time of this publication, jack return data were not available for Cultus from the 2009 brood year (2012 return year). The preliminary jack escapement estimate is 101 fish, however, this estimate does not include catch. The escapement estimate is below the time series (1948-2004) average for three year old recruits (1,000), and is below the recent (1980-2004) average (200);

Average four year old post-smolt (mostly marine) survival (R/smolt) for Cultus Sockeye declined from a peak of 15% in the late-1980 brood years (four year average at peak) to one of the lowest post-smolt survivals on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E).

For Cultus, the top ranked models are the MRJ, power (juv) (FrD-peak), and power (juv) (Pi) models (Table 5). Due to significant gaps in the smolt time-series that severely restricted the number of years that could be forecasted by certain smolt models (RJ1, RJ2 & RJC) with jack-knife analysis these models were excluded from the model evaluation process for this stock. In addition, all models that use EFS as a predictor variable were excluded, as EFS data for Cultus do not take into consideration the significant hatchery supplementation (fry & smolts) to this stock since the 2000 brood year. Forecasts produced by the top ranked models were similar, varying by 7% (Table 5). The top ranked MRJ model was used to generate the forecast for 2013, as it ranked first on average across performance measures (Table 5 in MacDonald & Grant 2012). Given the assumptions underlying the MRJ model, there is a one in four chance (25% probability) the Cultus Sockeye return will be below 3,000 (2% age-4 marine survival) and a three in four chance (75% probability) the return will be below 16,000 (9% age-4 marine survival) in 2013. The median (one in two chance: 50% probability) forecast of 7,000 (4% age-4 marine survival) is half the average return on this cycle (14,000) (Tables 1 & 2; Figure 3). The five year old component of the 2013 return is expected to contribute 5% of the total forecasted return (at the 50% probability level) (Table 3).

Late Shuswap (Shuswap-L CU)

The 2009 brood year was an 'off-cycle' year for the highly cyclic Late Shuswap stock. However, adult escapement for Late Shuswap in the 2009 brood year (20,200 EFS) was the highest on record for this cycle, falling well above the cycle average (1949-2005: 2,800 EFS) (Table 1, column C). Spawning success was 98%, falling above the long-term average for this stock (95%). Fry assessments were not conducted for Late Shuswap in the 2008 or the 2009 brood years (2009 & 2010 fry assessment years).

Average four year old productivity (R/EFS) for Late Shuswap Sockeye has been variable, with the largest peak of 10.8 R/EFS occurring in the early-1970 brood years (four year average at peak); this is one of the Fraser Sockeye stocks that has not exhibited systematic declines in productivity (Grant et al. 2010; Grant et al. 2011). Cycle-line productivity however, peaked in the early 1990's, and subsequently declined (Figure 3). Similar to other stocks, Late Shuswap exhibited amongst the lowest productivities on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3).

For Late Shuswap, the top ranked models are the R1C, Ricker-cyc, and RAC models (Table 5). Forecasts produced by the top ranked models were quite different, varying by up to 74% (Table 5). The R1C and RAC models produced similar low forecasts, since these non-parametric models do not use brood year EFS to forecast returns (Table 5). Given the high 2009 brood year escapement for Late Shuswap, the top ranked biological model (Ricker-cyc) was used to generate this forecast. The Ricker-cyc model also ranked high on average across performance measures, and it ranked high on each individual performance measure (Table 5 in MacDonald & Grant 2012). Given the assumptions underlying the Ricker-cyc model, there is a one in four chance (25% probability) the Late Shuswap Sockeye return will be below 36,000 (1.8 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 274,000 (13.5 age-4 R/EFS) in 2013. The median (one in two chance: 50% probability) forecast of 111,000 (5.5 age-4 R/EFS) is below the average return on this cycle (182,000) (Tables 1 & 2; Figure 3). The five year old component of the 2013 return is expected to contribute 0% of the total forecasted return (at the 50% probability level) (Table 3). Since this stock has particularly strong cyclic differences in annual abundance, a Larkin model forecast (ranked 5th) was also generated, and resulted in a relatively similar forecast to the Ricker-cyc model (Table 5). For further comparison, a standard Ricker model that does not take into consideration cyclic dominance also produced a similar forecast to the Ricker-cyc model forecast for Late Shuswap.

Portage (Seton-L (*de novo*) CU)

The 2009 brood year escapement for Portage (800 EFS) was less than one third of the cycle average (1953-2005: 2,900 EFS), and was the lowest on this cycle since 1969 (Table 1, column C). Spawning success in 2009 (87%) was also below average (94%).

Average four year old productivity (R/EFS) for Portage Sockeye declined from a peak of 61.7 R/EFS in the early 1960 brood years (four year average at peak), to one of the lowest productivities on record in the 2005 brood year (i.e. 2009 four year old return year (Table 2, columns B to E; Figure 3).

For Portage, the top ranked models are the Larkin, Ricker-cyc, and power models (Table 5). For each individual performance measure, the Larkin and Ricker-cyc models each ranked within the top 50% (10 out of 20) of all models compared for this stock; the power model ranked low on the MRE performance measure in particular (Table 5 in MacDonald & Grant 2012). Forecasts produced by the top models were similar, varying by 30% (Table 5). The Larkin model was used for the 2013 Portage forecast, as it ranked first on average across performance measures, and it ranked well on each individual performance measure (Table 5 in MacDonald & Grant 2012). Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Portage Sockeye return will be below 5,000 (6.1 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 28,000 (34.6 age-4 R/EFS) in 2013. The median (one in two chance: 50% probability) forecast of 12,000 (14.3 age-4 R/EFS) is well below the average return on this cycle (47,000) (Tables 1 & 2; Figure 3). The five year old component of the 2013 return is expected to contribute 1% of the total forecasted return (at the 50% probability level) (Table 3).

Weaver (Harrison (U/S)-L CU)

The 2009 brood year escapement for Weaver (12,900 EFS) was below the cycle average (1969-2005: 21,600 EFS) (Table 1, column C). Spawning success in Weaver Creek and the Weaver spawning channel was 44% and 82% respectively, both well below their long-term averages (89% and 92%). Early freshwater survival in the 2009 brood year (2,400 fry/EFS) was much higher than the cycle average (1,400 fry/EFS). Additionally, juvenile abundance (34.7 million fry) was greater than the 2009 cycle average (1969-2005 average: 28 million fry).

Average four year old productivity (R/EFS) for Weaver Sockeye has been variable, with the largest peak of 41.8 R/EFS occurring in the late-1960 brood years (four year average at peak). This stock has not exhibited systematic productivity trends through time (Grant et al. 2011; Peterman & Dorner 2012). Similar to other stocks, however, Weaver exhibited amongst the lowest productivity on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3).

For Weaver, the top ranked models are the MRS, Ricker (PDO), and RJC (Table 5). For each individual performance measure, none of the top models ranked within the top 50% (17 out of 33) of all models compared for this stock (Table 5 in MacDonald & Grant 2012); the MRS model ranked particularly low on the MPE performance measure, and the Ricker (PDO) and RJC models ranked poorly on the MRE performance measure. Forecasts produced by the top ranked models varied by 41% (Table 5). The RJC model generated the highest forecast, attributed to higher freshwater survival observed for this stock in the brood year. The MRS model was used for the 2013 Weaver forecast, as it ranked first on average across performance measures (Table 5 in MacDonald & Grant 2012). Given the assumptions underlying the MRS model, there is a one in four chance (25% probability) the Weaver Sockeye return will be below 76,000 (5.9 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 281,000 (21.6 age-4 R/EFS) in 2013. The median (one in two chance: 50% probability) forecast of 147,000 (11.2 age-4 R/EFS) is below the average return on this cycle (281,000) (Tables 1 & 2; Figure 3). The five year old component of the 2013 return is expected to contribute 1% of the total forecasted return (at the 50% probability level) (Table 3).

Birkenhead (Lillooet-Harrison-L CU)

The 2009 brood year escapement for Birkenhead (34,500 EFS) was close to, though larger than, the cycle average (28,100 EFS) from 1949-2005 (Table 1, column C). Spawning success in 2009 was 100%, much higher than the long-term average (92%).

Average four year old productivity (R/EFS) for Birkenhead Sockeye declined from a peak of 21.5 R/EFS in the early 1970 brood years (four year average at peak), to one of the lowest productivities on record in the 2005 brood year (i.e. 2009 four year old return year) (Table 2, columns B to E; Figure 3).

For Birkenhead, the top ranked models are the Ricker (Ei), RAC (tied second), and Ricker (tied second) (Table 5). For each individual performance measure, no top model ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5 in MacDonald & Grant 2012). Forecasts produced by the top ranked models were similar, varying by 17% (Table 5). The first ranked Ricker (Ei) model was used for the 2013 Birkenhead forecast (Table 5). Given the assumptions underlying the Ricker (Ei) model, there is a one in four chance (25% probability) the Birkenhead Sockeye return will be below 160,000 (3.2 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 492,000 (12.5 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 282,000 (6.5 age-4 R/EFS) is just below the average return on this cycle (310,000) (Tables 1 & 2; Figure 3). The five year old component of the 2013 return is expected to contribute 21% of the total forecasted return (at the 50% probability level) (Table 3). The Ricker (Ei) produced a higher forecast than the standard

Ricker model with no covariate, given that ocean sea surface temperatures were cooler in the smolt outmigration years.

Fraser Pink Salmon

The power model with an environmental covariate (specifically, average sea-surface salinity from July to September at the Race Rocks and Amphitrite Point lighthouse stations) ranked first in a previously-run retrospective analysis (DFO 2006). The 2013 Pink forecast ranges from 6.4 million to 12.5 million fish at the 25% to 75% probability levels (Table 1). The median (50% probability) forecast of 8.9 million Pink Salmon is below the long-term (1959-2011) average return (12.6 million) (Table 1). This forecast is smaller than the second ranked power model with no environmental co-variate (25% to 75% p-level: 9.4 million to 20.2 million; 50% p-level: 14.0 million). The lower forecast for the power model with a sea-surface-salinity co-variate is attributed to below average sea-surface-salinity in the Juan de Fuca (Race Rocks lighthouse station) and West Coast of Vancouver Island (Amphitrite Point lighthouse station) in the summer (July to August).

The 2013 Pink forecast is highly uncertain, as estimation methods for Pink recruitment have changed significantly over time. Specifically, in recent years (post-2001), recruitment is estimated using test fishery indices of abundance, rather than direct measures of escapement and catch, as was used in previous years.

ENVIRONMENTAL CONDITIONS

Salmon forecasts remain highly uncertain, in large part due to wide variability in annual salmon productivity (recruits-per-spawner). For Fraser Sockeye stocks in particular, quantitative and qualitative indicators of productivity explored to date have not reduced forecast uncertainty significantly and remain an active area of research. The uncertainty in Fraser Sockeye productivity is likely attributed to the broad range of environments these stocks occupy throughout their life-history. Fraser Sockeye generally spend their first two winters in freshwater (egg through to smolt stage), followed by one to three winters in the marine environment, before returning to their natal streams or lakes to spawn. Specifically in the marine environment, Fraser Sockeye stocks migrate through a broad range of systems within their first year of marine residence, moving rapidly northwards through the Strait of Georgia (Preikshot et al. 2012), exiting this water body via the Johnstone Strait, migrating along the continental shelf, and finally moving off the shelf into the North Pacific in the winter months (Tucker et al. 2009). Considerable mortality and inter-annual variability in mortality occurs in these ecosystems, as indicated by freshwater and marine survival data collected for Chilko River Sockeye (Fraser Sockeye indicator stock). Therefore, it is likely that a number of factors in both the freshwater and marine environments influence Fraser Sockeye productivity, and these factors may vary between stocks and years.

Certain environmental variables have been explored quantitatively in the forecast process. In particular, sea surface temperature measured in the Strait of Georgia is one variable explored as a covariate in stock-recruitment forecast models for Fraser Sockeye stocks. Although this variable only has a negligible effect on Fraser Sockeye forecasts, models that include this co-variate have performed better than models that do not for certain stocks. Above average sea surface temperatures in the Strait of Georgia during Fraser Sockeye smolt migration tend to decrease Sockeye forecasts slightly, and temperatures below average tend to increase forecasts, since warmer ocean temperatures generally decrease salmon survival and cooler temperatures generally improve survival (Mueter et al. 2002). Since 2008 (including the 2011 smolt outmigration year for most Fraser Sockeye returning in 2013), La Niña conditions have resulted in cooler than average temperatures in the eastern North Pacific Ocean, where Fraser Sockeye rear as juveniles. Sea surface water temperatures measured at lighthouse stations along coastal British Columbia and in the Strait of Georgia, also indicate cooler than average

temperatures in 2011 (Irvine & Crawford 2012). In cases where sea surface temperature covariate models ranked in the top three models for a particular stock, models that include this covariate produced higher 2013 forecasts than models without this covariate (Table 5).

As work proceeds on identifying potential indicators of salmon productivity in both the freshwater and marine ecosystems, presentations of environmental-recruitment correlations will benefit from describing the uncertainties of these relationships. For a forecast, Bayesian prediction intervals can be used quantitatively to describe the uncertainty in the model fit to the data, or qualitatively, to frame out the ability of a particular correlation to distinguish between different survival conditions using the overlap between prediction intervals over the time series. For example, using Peterson's (National Ocean and Atmospheric Administration: NOAA) stop light approach, Bayesian prediction intervals may demonstrate that many environmental variables can only be used to resolve two categories of survival conditions, such as Red/Amber (low to average) and Amber/Green (average to high), rather than the three categories typically presented (Red, Amber, and Green). For Fraser Sockeye, further work is anticipated to see if a multi-criteria stop light approach that includes the use of Bayesian methods, can reduce uncertainty in the official quantitative forecasts.

DISCUSSION

The 2013 forecast distribution is larger than the 2012 forecast. Although the 2009 return (brood year for 2013 four year old returns) was associated with record low productivity for almost all stocks, resulting escapements (or smolt abundances, where available) for many stocks were still larger than the previous year's escapements (2008). Most significantly, brood year smolt abundances and escapements for Chilko and Quesnel were much higher in the 2009 brood year (35 million and 82,300) than in the 2008 brood year (11.8 million and 2,500). As a result, the Chilko 50% probability forecast is 1.8 million in 2013 compared to 562,000 in 2012, and the Quesnel forecast is 1.2 million in 2013 compared to 67,000 in 2012. These two stocks contribute the greatest proportion (78%) to the 2013 forecast.

A single forecast scenario is presented for 2013 (Table 1), similar to 2012. In the 2013 forecast scenario, the suite of appropriate candidate models was evaluated for each stock across the entire time-series (see Table 5 in MacDonald & Grant 2012). However, given the recent improvements to stock productivity, and the lack of stock specific productivity data post-2005 to inform the recent productivity models introduced in 2010 (Kalman Filter Ricker model, RS4yr, RS8yr), these models were excluded from consideration in the 2013 forecast process.

Although productivity in the 2006 to 2008 brood years (corresponding to 2010 to 2012 return years) has improved, following a multi-decadal period of systematic declines in productivity for most stocks (Grant et al. 2010; Grant et al. 2011; Grant et al. 2012; Peterman & Dorner 2011), in the absence of leading indicators, it is unclear whether average productivity will persist through to 2013. To understand the potential range in returns that might be expected under low or conversely high productivities, respectively low (10% to 20%) and high (75% to 90%) probability level forecasts are presented. Productivities associated with each stock's forecast at these different probability levels are presented in both tabular and graphical form (Table 2; Figure 3), so they can be placed in the context of historical productivity levels for each stock. The median forecast (50% probability level) generally represents long-term average productivity for each stock. Therefore, when stock productivities are average, returns will fall at this median probability level, as was seen in the 2011 and 2012 return years (see Figures 3 & 4). If productivity falls below average, in the range seen within the past decade for most stocks (1995-2005 brood years), returns will fall at the lowest end of the probability distribution (10% probability level) (Figures 3 & 4). Conversely, if productivity falls near the historical time series maximum, returns will fall at the highest end of the probability distribution (90% probability level) (Figures 3 & 4).

Due to uncertainty in stock productivity through to 2013, an additional sensitivity analysis was conducted as part of the 2013 forecast process to explore model performance over the generally low productivity stock-recruitment time series from the 1997 to 2004 brood years (low productivity period). This scenario could occur if stock productivities observed in the last decade (excluding very recent 2010 to 2012 return years) have resumed. Unlike the 2013 forecast, the 2013 'Recent Model Performance' sensitivity analysis evaluates the performance of all candidate models, including the recent productivity models added in the 2010 forecast (KF, RS4yr, RS8yr). Model performance was evaluated over the low productivity period observed for most stocks (1997-2004 brood years). The median 'Recent Model Performance' forecast falls at the low end of the presented 2013 forecast distribution. This is due to the models selected, which, for a number of stocks primarily relied on data from the low productivity period (to 2005). This scenario can be used in-season if there are early indications that productivity has returned to below average. Alternatively, the low end of the presented 2013 forecast distribution could be emphasized, similar to what occurs during the in-season process.

RECOMMENDATIONS

- In attempts to improve the predictability of Fraser Sockeye productivity, return forecasts have incorporated environmental variables, both quantitatively into forecast models (Grant et al. 2010; Grant & MacDonald 2012), and qualitatively into forecast advice (DFO 2009). However, to date, the inclusion of environmental variables has not significantly decreased forecast uncertainty (i.e. it has not significantly explained annual productivity). Future Fraser Sockeye forecast work should involve research and workshops that explore environmental variables that could be used to explain inter-annual variability in Fraser Sockeye recruitment.
- Future work on juvenile abundance is required to generate more information on separate marine and freshwater survival trends to better understand what contributes to Fraser Sockeye population dynamics; currently only a single indicator system (Chilko Sockeye) exists, and it is unlikely that this freshwater environment is an indicator of freshwater survival in other systems.
- Future work on the forecast R-code is highly recommended. The addition of new approaches and modifications each year has left the existing code in need of an overhaul. Also, advances in the available statistical packages could stream-line the existing code considerably. This will require resources outside of the existing program, as sufficient resources are currently not available.
- More juvenile Sockeye work is required to continue to understand freshwater and marine mechanisms influencing Fraser Sockeye productivity.

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Table 1. Fraser Sockeye forecasts for 2013 are presented by stock and timing group from the 10% to 90% probability levels (columns A and H to L). The selected models for each stock are presented in column B. Average run sizes are presented across all cycles (F) and for the 2013 cycle (G). Brood year escapements (smolts for Chilko and Cultus) for four (2009) and five year old (2008) recruits returning in 2013 (columns C & D) are presented and colour coded relative to their cycle average from 1949-2005 (brood year). Forecasted returns (column E), corresponding to the 50% probability level (column J) are also colour coded relative to their cycle average. Color codes represent the following: red (< average), yellow (average) and green (> average).

A	B	C	D	E	F	G	H	I	J	K	L
Run timing group		BY (09)	BY (08)	Ret	Mean Run Size		Probability that Return will be at/or Below Specified Run Size [a]				
Stocks	Forecast Model [b]	(EFS)	(EFS)	2013	all cycles [c]	2013 cycle [d]	10%	25%	50%	75%	90%
Early Stuart	*Ricker (Ei)*	21,900	11,100		311,000	792,000	92,000	137,000	211,000	331,000	507,000
Early Summer					478,000	274,000	73,000	130,000	253,000	468,000	844,000
(total excluding miscellaneous)					*478,000*	*274,000*	55,000	94,000	180,000	342,000	621,000
Bowron	*MRS*	1,000	800		39,000	24,000	2,000	3,000	7,000	14,000	26,000
Fennell	*Power*	700	200		25,000	12,000	3,000	5,000	9,000	15,000	25,000
Gates	*Larkin*	5,100	1,600		53,000	40,000	24,000	37,000	67,000	115,000	191,000
Nadina	*MRJ*	3,700	10,200		80,000	72,000	10,000	20,000	44,000	95,000	189,000
Pitt	*Larkin*	18,100	5,400		72,000	74,000	5,000	9,000	15,000	28,000	50,000
Scotch	*Ricker*	1,700	100		78,000	25,000	4,000	8,000	17,000	39,000	82,000
Seymour	*Ricker-cyc*	3,100	800		131,000	27,000	7,000	12,000	21,000	36,000	58,000
Misc (EShu & Taseko) [e]	*RS (Sc/Se)+RS(Chilko)*	1,100	400		NA	NA	2,000	4,000	13,000	18,000	20,000
Misc (Chilliwack) [f]	*RS (Esum)*	2,200	13,700		NA	NA	15,000	31,000	57,000	103,000	194,000
Misc (Nahatlatch) [f]	*RS (Esum)*	200	150		NA	NA	1,000	1,000	3,000	5,000	9,000
Summer					3,822,000	6,791,000	1,222,000	2,095,000	3,718,000	6,663,000	12,131,000
(total excluding miscellaneous)					*3,822,000*	*6,791,000*	1,218,000	2,088,000	3,705,000	6,637,000	12,079,000
Chilko [g]	*Power (juv) (PI)*	35 M	11.8 M		1,350,000	824,000	736,000	1,147,000	1,829,000	2,929,000	4,482,000
Late Stuart	*Power*	43,300	57,900		560,000	1,654,000	80,000	151,000	333,000	686,000	1,393,000
Quesnel	*Ricker-cyc*	62,800	2,500		1,358,000	3,956,000	277,000	596,000	1,218,000	2,445,000	5,188,000
Stellako	*Larkin*	15,800	71,100		462,000	245,000	91,000	131,000	192,000	291,000	423,000
Raft [h]	*Ricker (PDO)*	6,000	3,500		32,000	28,000	22,000	32,000	51,000	81,000	124,000
Harrison [h,i]	*Ricker (Ei)*	100,500	399,661		60,000	84,000	**12,000	**31,000	**82,000	**205,000	**469,000
Misc (N. Thomp. Tribs) [h,j]	*R/S (Ra/Fe)*	70	200		NA	NA	100	300	1,000	1,000	2,000
Misc (N. Thomp River) [h,j]	*R/S (Ra/Fe)*	1,700	3,000		NA	NA	4,000	7,000	12,000	25,000	50,000
Late					2,960,000	834,000	167,000	293,000	583,000	1,133,000	2,126,000
(total exlcuding miscellaneous)					*2,960,000*	*834,000*	160,000	280,000	559,000	1,091,000	2,053,000
Cultus [g]	*MRJ*	374,000	145,300		39,000	14,000	2,000	3,000	7,000	16,000	33,000
Late Shuswap	*Ricker-cyc*	29,200	900		2,152,000	182,000	14,000	36,000	111,000	274,000	574,000
Portage	*Larkin*	800	60		40,000	47,000	2,000	5,000	12,000	28,000	61,000
Weaver	*MRS*	12,900	600		363,000	281,000	42,000	76,000	147,000	281,000	506,000
Birkenhead	*Ricker (Ei)*	11,500	6,800		366,000	310,000	100,000	160,000	282,000	492,000	879,000
Misc. non-Shuswap [k]	*R/S (Lillooet-Harrison)*	3,700	200		NA	NA	7,000	13,000	24,000	42,000	73,000
TOTAL SOCKEYE SALMON					-	-	1,554,000	2,655,000	4,765,000	8,595,000	15,608,000
(TOTAL excluding miscellaneous)					*(7,571,000)*	*(8,579,000)*	*(1,529,000)*	*(2,606,000)*	*(4,662,000)*	*(8,427,000)*	*(15,312,000)*
		2011 Brood Year Fry									
TOTAL PINK SALMON	*Power (SSS)*	720 M			12,580,000	12,580,000	4,794,000	6,401,000	8,926,000	12,473,000	17,111,000

a. Probability that return will be at, or below, specified projection.
b. See Table 5 for model descriptions.
c. Sockeye: 1953-2009 (depending on start of time series)
d. Sockeye: 1953-2009 (depending on start of time series)
e. Misc: Early Shuswap stocks use Scotch and Seymour R/EFS in forecast; Misc: Taseko uses Chilko R/EFS in forecast.
f. Misc: Chilliwack & Nahatlach use Early Summer Run stocks: R/EFS in forecast.
g. Brood year smolts in columns C & D (not effective females).
h. Raft, Harrison, Miscellaneous North Thompson stocks moved in current forecast to Summer Run timing group due to changes in run timing of these stocks.
i. Harrison are age-4 (column C) and age-3 (column D).
j. Misc: North Thompson stocks use Raft & Fennel R/EFS in forecast.
k. Misc: Late Run stocks (Harrison Lake down stream migrants including Big Silver, Cogburn, etc.) use Birkenhead R/EFS in forecast.

** Harrison forecasts are extremely uncertain due to age-proportion variations and brood year escapements (2009/2010) that are out of the historical data range.

Definitions: BY: Brood year; BY09: brood year 2009; BY08: brood year 2008; EFS: effective female spawners; Ei (Entrance Island sea-surface-temperature); PDO (Pacific Decadal Oscillation); PI (Pine Island sea-surface temperature).

Table 2. For each of the 19 forecasted stocks (column A), geometric average four-year old productivities are presented for the entire time series (brood years: 1948-2005) (column B), the highest four consecutive peak years (column C), the recent four year low productivity period (brood years: 2002-2005) (column D), and the 2005 brood year (amongst the lowest productivity on record for all stocks) (column E). Four-year old productivities associated with the various probability levels of the 2013 forecast (based on Table 1 forecasts and escapements) are presented in columns (F) to (J) for comparison. Forecast productivities are presented as R/EFS. Colour codes represent the following: Red (< average), yellow (average) and green (>average).

A	B	C	D	E	F	G	H	I	J
Run timing group Stocks	**Average**	**Peak Average (four consecutive yrs)**	**Avg R/EFS (2002-2005)**	**2005 Brood Year**	**2013 forecast productivities (R/EFS) for each probability level in Table 3 by stock**				
					10%	**25%**	**50%**	**75%**	**90%**
Early Stuart	6.4	24.5	2.1	1.6	3.4	5.5	8.9	14.2	22.5
Early Summer									
Bowron	6.8	20.4	2.3	2.2	1.7	3.2	6.4	12.8	23.8
Fennell	7.3	53.5	2.6	0.4	2.9	5.2	9.6	18.4	33.2
Gates	9.5	41.0	3.0	1.6	3.8	6.2	12.2	21.2	35.5
Nadina	6.0	13.5	3.5	1.0	1.8	3.6	7.8	16.8	33.6
Pitt (age5 prod) [a]	3.5	13.3	0.5	0.2	0.1	0.2	0.4	0.7	1.1
Scotch	6.7	21.5	3.4	2.1	1.5	2.8	6.4	14.6	30.4
Seymour	7.7	29.2	3.6	3.4	2.0	3.7	6.5	11.7	18.4
Summer									
Chilko (% R/smolt) [b]	7%	18%	2%	0.3%	2%	3%	5%	8%	13%
Late Stuart	9.3	57.2	2.1	0.7	1.3	2.6	6.3	13.8	27.7
Quesnel [c]	9.4	18.1	0.5	0.3	3.3	7.2	14.7	29.5	62.6
Stellako	7.0	15.1	0.7	0.1	2.4	3.5	5.7	10.0	16.6
Raft	6.0	13.6	1.6	0.4	1.8	3.2	5.9	10.6	18.3
Harrison [d]	7.4	33.8	6.9	0.1	NA	NA	NA	NA	NA
Late									
Cultus (% R/smolt) [b]	4%	15%	1%	1%	1%	2%	4%	9%	18%
Late Shuswap [c]	9.4	10.8	1.5	3.0	0.6	1.8	5.5	13.5	28.4
Portage	13.4	61.7	2.0	0.3	2.9	6.1	14.3	34.6	76.6
Weaver	11.7	41.8	3.9	1.7	3.3	5.9	11.2	21.6	38.9
Birkenhead	5.6	21.5	0.9	1.2	1.6	3.2	6.5	12.5	23.6

a. Pitt is dominated by five-year olds, therefore, five-year old productivity is presented; however, since four-year olds contribute a higher proportion than average, 2013 five-year old productivities are not directly comparable to average productivities in columns B to E.
b. Chilko and Cultus are marine survival (recruits per smolt)
c. Quesnel and Late Shuswap are cycle averages
d. Harrison is presented as total productivity given the variable four year old proportion; therefore, forecasts could not be compared (NA)

Table 3. Age composition of forecasted returns for each stock at the 50% probability level.

Sockeye stock/timing group	2013 Fraser Sockeye Forecasts				
	Model	FOUR YEAR OLDS 50%[a]	FIVE YEAR OLDS 50%[a]	TOTAL 50%[a]	Four Year Old Proportion
Early Stuart	*Ricker (Ei)*	**195,000**	**16,000**	**211,000**	**92%**
Early Summer		**185,000**	**68,000**	**253,000**	**73%**
Bowron	*MRS*	6,000	1,000	7,000	86%
Fennell	*Power*	7,000	2,000	9,000	78%
Gates	*Larkin*	64,000	3,000	67,000	96%
Nadina	*MRJ*	29,000	15,000	44,000	66%
Pitt	*Larkin*	13,000	2,000	15,000	87%
Scotch	*Ricker*	17,000	0	17,000	100%
Seymour	*Ricker -cyc*	20,000	1,000	21,000	95%
Misc (EShu & Taseko)	*RS*	13,000	0	13,000	100%
Misc (Chilliwack)	*RS*	14,000	43,000	57,000	25%
Misc (Nahatlatch)	*RS*	2,000	1,000	3,000	67%
Summer		**3,402,500**	**315,500**	**3,718,000**	**92%**
Chilko	*Power (juv) (Pi)*	1,695,000	134,000	1,829,000	93%
Late Stuart	*Power*	272,000	61,000	333,000	82%
Quesnel	*Ricker-cyc*	1,217,000	1,000	1,218,000	100%
Stellako	*Larkin*	90,000	102,000	192,000	47%
Raft	*Ricker (PDO)*	36,000	15,000	51,000	71%
Harrison[b]	*Ricker (Ei)*	82,000	0	82,000	100%
Misc (N. Thomp. Tribs)	*RS*	500	500	1,000	50%
Misc (N. Thomp River)	*RS*	10,000	2,000	12,000	83%
Late		**516,900**	**66,400**	**583,000**	**89%**
Cultus	*MRJ*	6,900	400	7,300	95%
Late Shuswap	*Ricker-cyc*	111,000	0	111,000	100%
Portage	*Larkin*	11,000	1,000	12,000	92%
Weaver	*MRS*	145,000	2,000	147,000	99%
Birkenhead	*Ricker (Ei)*	223,000	59,000	282,000	79%
Misc. non-Shuswap	*RS*	20,000	4,000	24,000	83%
Total		**4,299,400**	**465,900**	**4,765,000**	**90%**

a. Probability that actual return will be at or below specified run size
b. Age comp. for Quesnel and Stellako are calculated using the proportions that would be applied by a bio. model
c. Harrison are age-4 (in four year old columns) and age-3 (in five year old columns) forecasts

Table 4. List of candidate models organized by their two broad categories (non-parametric and biological) with descriptions. Models that emphasize recent stock productivity are indicated. Models are described in detail in Appendices 1 to 3 of Grant et al. (2010). Where applicable, models use effective female spawner data (EFS) as a predictor variable unless otherwise indicated by '(juv)' or '(smolt)' next to the model (Table 2), where fry data or smolt data are used instead.

MODEL CATEGORY		DESCRIPTION
A. Non-Parametric Models		
R1C	(recent productivity)	Return from 4 years previous
R2C	(recent productivity)	Average return from 4 & 8 years previous
RAC		Average return on the cycle line on the time series
TSA		Average return across all cycles lines on the time series
RS1	(recent productivity)	Product of average productivity from 4 years previous and EFS (or juv/smolt)
RS2	(recent productivity)	Product of average productivity from 4 & 8 years previous and EFS (or juv/smolt)
RS4yr	(recent productivity)	Product of average productivity from the last 4 years and EFS (or juv/smolt)
RS8yr	(recent productivity)	Product of average productivity from the last 4 & 8 years and EFS (or juv/smolt)
MRS		Product of average productivity from entire time series and brood year EFS (or juv/smolt)
RSC		Product of average cycle-line productivity (entire time-series) and brood year EFS (or juv/smolt)
RS (used for miscellaneous stocks)		Product of average productivity on time series for specified stocks and EFS (or juv/smolt)
B. Biological Models		
power		Bayesian
power-cyc		Bayesian (cycle line data only)
Ricker		Bayesian
Ricker-cyc		Bayesian (cycle line data only)
Larkin		Bayesian
Kalman Filter Ricker	(recent productivity)	Bayesian
Smolt-jack		Bayesian
C. Biological Models Covariates		(e.g. Power (FrD-mean))
FrD-mean		Mean Fraser discharge (April - June)
Ei		Entrance Island spring sea-surface temperature
Pi		Pine Island spring sea-surface temperature
FrD-peak		Peak Fraser Discharge
PDO		Pacific Decadal Oscillation
SSS		Sea Surface Salinity (Race Rocks & Amphitrite Point light house stations) from July to September

Table 5. Top three ranked model forecasts evaluated for each stock for the 2013 forecast. Model ranks determined from previous year's jackknife analysis results (MacDonald & Grant 2012) and four performance measures (mean raw error: MRE, mean absolute error: MAE, mean proportional error: MPE, and root mean square error: RMSE).

RUN TIMING GROUP: EARLY STUART

	Rank	Return Forecast				
EARLY STUART		**10%**	**25%**	**50%**	**75%**	**90%**
Ricker (Ei)	**1**	**92,000**	**137,000**	**211,000**	**331,000**	**507,000**
Ricker (Pi)	1	79,000	117,000	185,000	288,000	438,000
Ricker	3	59,000	95,000	157,000	257,000	429,000
Ricker (PDO)	3	77,000	114,000	174,000	278,000	415,000

RUN TIMING GROUP: EARLY SUMMER

	Rank	Return Forecast				
BOWRON		**10%**	**25%**	**50%**	**75%**	**90%**
MRS	**1**	**2,000**	**3,000**	**7,000**	**14,000**	**26,000**
Ricker (Pi)	2	3,000	5,000	8,000	14,000	23,000
Ricker (Ei)	3	3,000	5,000	9,000	15,000	25,000

	Rank	Return Forecast				
FENNELL		**10%**	**25%**	**50%**	**75%**	**90%**
Power	**1**	**3,000**	**5,000**	**9,000**	**15,000**	**25,000**
RAC	2	3,000	6,000	12,000	23,000	42,000
Ricker	3	4,000	7,000	12,000	23,000	43,000

	Rank	Return Forecast				
GATES		**10%**	**25%**	**50%**	**75%**	**90%**
RAC	1	14,000	22,000	38,000	64,000	103,000
R2C	2	11,000	19,000	35,000	63,000	107,000
Larkin	**3**	**24,000**	**37,000**	**67,000**	**115,000**	**191,000**
MRS	3	12,000	24,000	51,000	110,000	217,000

	Rank	Return Forecast				
NADINA		**10%**	**25%**	**50%**	**75%**	**90%**
MRJ	**1**	**10,000**	**20,000**	**44,000**	**95,000**	**189,000**
Ricker (FrD-peak)	2	13,000	21,000	38,000	65,000	103,000
Power (juv) (FrD-peak)	2	18,000	28,000	47,000	74,000	122,000

	Rank	Return Forecast				
PITT		**10%**	**25%**	**50%**	**75%**	**90%**
Larkin	**1**	**5,000**	**9,000**	**15,000**	**28,000**	**50,000**
TSA	2	20,000	37,000	72,000	141,000	260,000
Ricker (PDO)	3	8,000	13,000	23,000	41,000	72,000

	Rank	Return Forecast				
SCOTCH		**10%**	**25%**	**50%**	**75%**	**90%**
Larkin	1	500	900	2,000	4,000	9,000
Ricker	**2**	**4,000**	**8,000**	**17,000**	**39,000**	**82,000**
RS1	3	1,000	2,000	5,000	16,000	43,000

	Rank	Return Forecast				
SEYMOUR		**10%**	**25%**	**50%**	**75%**	**90%**
Ricker-cyc	**1**	**7,000**	**12,000**	**21,000**	**36,000**	**58,000**
R1C	2	2,000	4,000	8,000	16,000	30,000
Larkin	2	7,000	12,000	21,000	37,000	67,000

RUN TIMING GROUP: SUMMER

CHILKO	Rank	Return Forecast 10%	25%	50%	75%	90%
Power (juv) (Pi)	**1**	**736,000**	**1,147,000**	**1,829,000**	**2,929,000**	**4,482,000**
Larkin	1	569,000	898,000	1,375,000	2,200,000	3,700,000
Power (juv)	3	778,000	1,150,000	1,882,000	2,995,000	4,617,000

LATE STUART	Rank	Return Forecast 10%	25%	50%	75%	90%
R1C	1	21,000	51,000	133,000	349,000	830,000
R2C	2	47,000	113,000	296,000	775,000	1,846,000
Power	**3**	**80,000**	**151,000**	**333,000**	**686,000**	**1,393,000**

QUESNEL	Rank	Return Forecast 10%	25%	50%	75%	90%
R1C	1	50,000	100,000	216,000	465,000	928,000
R2C	2	419,000	858,000	1,904,000	4,226,000	8,660,000
Ricker-cyc	**3**	**277,000**	**596,000**	**1,218,000**	**2,445,000**	**5,188,000**
Larkin	5	368,000	642,500	1,139,500	1,949,000	3,482,800
Ricker	7	198,000	383,000	844,000	1,770,000	3,425,000
Power (fry): four year old forecast	-	81,000	189,000	547,000	1,438,000	3,307,000
Ricker-cyc: four year old forecast	-	276,000	595,000	1,217,000	2,445,000	5,185,000
Ricker (EFS): four year old forecast	-	191,000	373,000	832,000	1,748,000	3,424,000

STELLAKO	Rank	Return Forecast 10%	25%	50%	75%	90%
R2C	1	49,000	85,000	156,000	286,000	494,000
Larkin	**2**	**91,000**	**131,000**	**192,000**	**291,000**	**423,000**
Ricker (Ei)	3	149,000	221,000	345,000	551,000	881,000

RAFT	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker (PDO)	**1**	**22,000**	**32,000**	**51,000**	**81,000**	**124,000**
Ricker-cyc	2	14,000	24,000	38,000	63,000	109,000
Power	2	15,000	24,000	37,000	57,000	89,000

HARRISON	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker (Ei)	**1**	**12,000**	**31,000**	**82,000**	**205,000**	**469,000**
Ricker (FrD-peak)	2	14,000	29,000	69,000	191,000	461,000
R2C	2	91,000	191,000	430,000	973,000	2,026,000
Power	7	36,000	68,000	155,000	316,000	675,000

RUN TIMING GROUP: LATE

CULTUS	Rank	Return Forecast 10%	25%	50%	75%	90%
MRJ	**1**	**2,000**	**3,000**	**7,000**	**16,000**	**33,000**
Power (juv) (FrD-peak)	2	2,000	4,000	7,000	15,000	33,000
Power (juv) (Pi)	3	2,000	4,000	8,000	16,000	34,000

LATE SHUSWAP	Rank	Return Forecast 10%	25%	50%	75%	90%
R1C	1	7,000	15,000	37,000	92,000	206,000
Ricker-cyc	**2**	**14,000**	**36,000**	**111,000**	**274,000**	**574,000**
RAC	3	6,000	13,000	29,000	66,000	137,000
Lakin	5	26,000	66,000	138,000	295,000	519,000
Ricker	7	18,000	43,000	106,000	232,000	398,000

PORTAGE	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin	**1**	**2,000**	**5,000**	**12,000**	**28,000**	**61,000**
Ricker-cyc	2	1,000	3,000	9,000	25,000	78,000
Power	3	3,000	6,000	13,000	30,000	59,000

WEAVER	Rank	Return Forecast 10%	25%	50%	75%	90%
MRS	**1**	**42,000**	**76,000**	**147,000**	**281,000**	**506,000**
Ricker (PDO)	2	62,000	107,000	196,000	354,000	666,000
RJC	3	74,000	132,000	248,000	467,000	827,000

BIRKENHEAD	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker (Ei)	**1**	**100,000**	**160,000**	**282,000**	**492,000**	**879,000**
RAC	2	53,000	117,000	281,000	678,000	1,496,000
Ricker	2	90,000	137,000	234,000	454,000	757,000

FRASER PINK SALMON

PINK	Rank	Return Forecast 10%	25%	50%	75%	90%
Power (Sea Surface Salinty)	**1**	**4,794,000**	**6,401,000**	**8,926,000**	**17,111,000**	**12,473,000**
Power	2	6,881,000	9,369,000	14,010,000	20,165,000	27,687,000

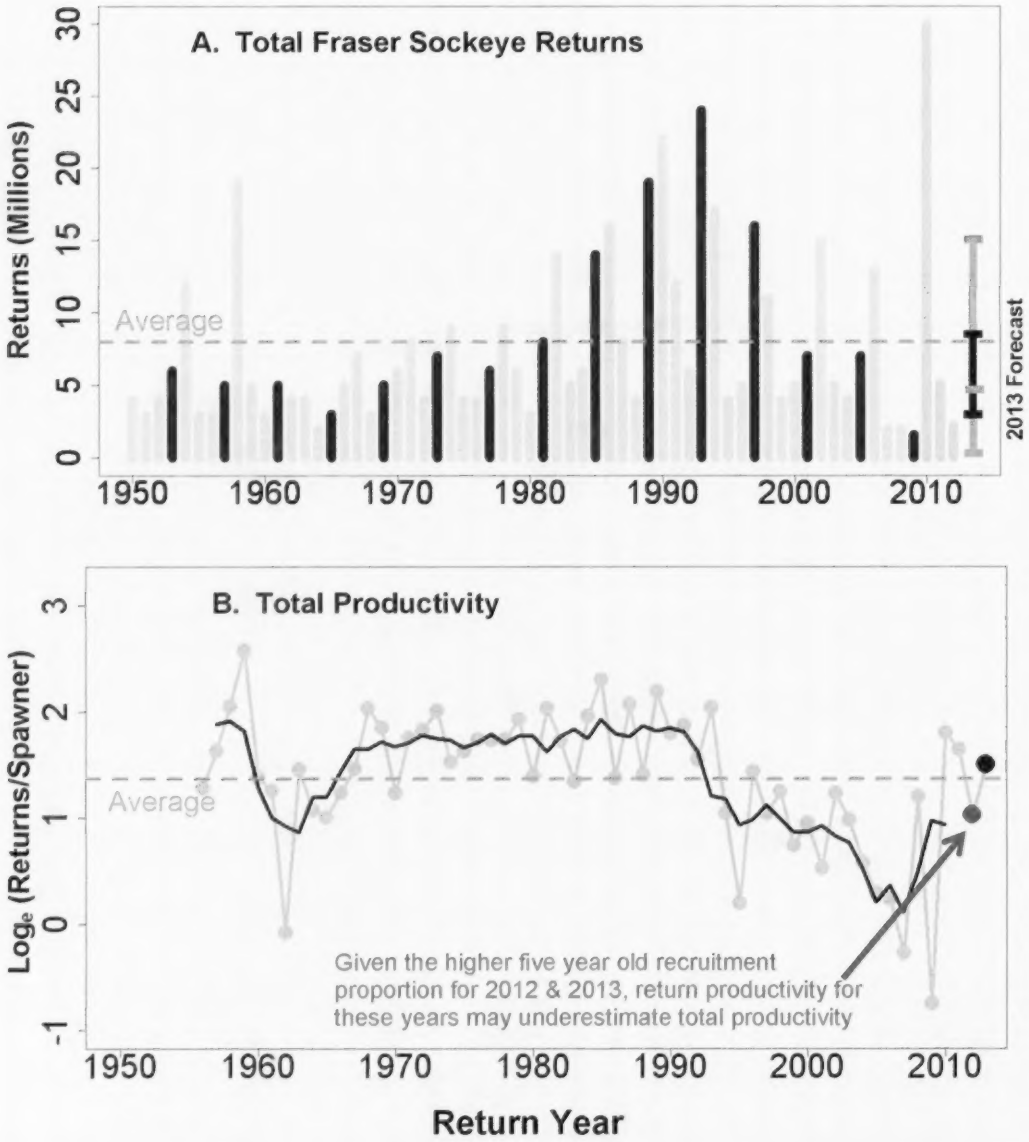

Figure 1. A. Total Fraser Sockeye annual returns (blue bars for the 2009 cycle and black bars for three other cycles). Grey bars from 2009 to 2010 are preliminary return data and 2011 & 2012 are in-season return data, which are all subject to change. The vertical bar aligned with the 2013 on the x-axis, represents the 2013 forecast (width of blue bars are the 10% to 90% p-level, width of black bars are the 25% to 75% p-level, and the red horizontal bar represents the 50% p-level). ***B. Total Fraser Sockeye productivity ($\log_e$(returns/total spawner)) up to the 2013 return year****. The light grey line presents annual productivity and the black line presents the smoothed four year running average. Return data for 2009 and 2010 are preliminary, for 2011 and 2012 are in-season estimates only, and for 2013 are based on the current forecast at the 50% p-level.*

(Escapement data are provided by DFO & return data are provided by the Pacific Salmon Commission. Red dashed line in both plots is the time series average)

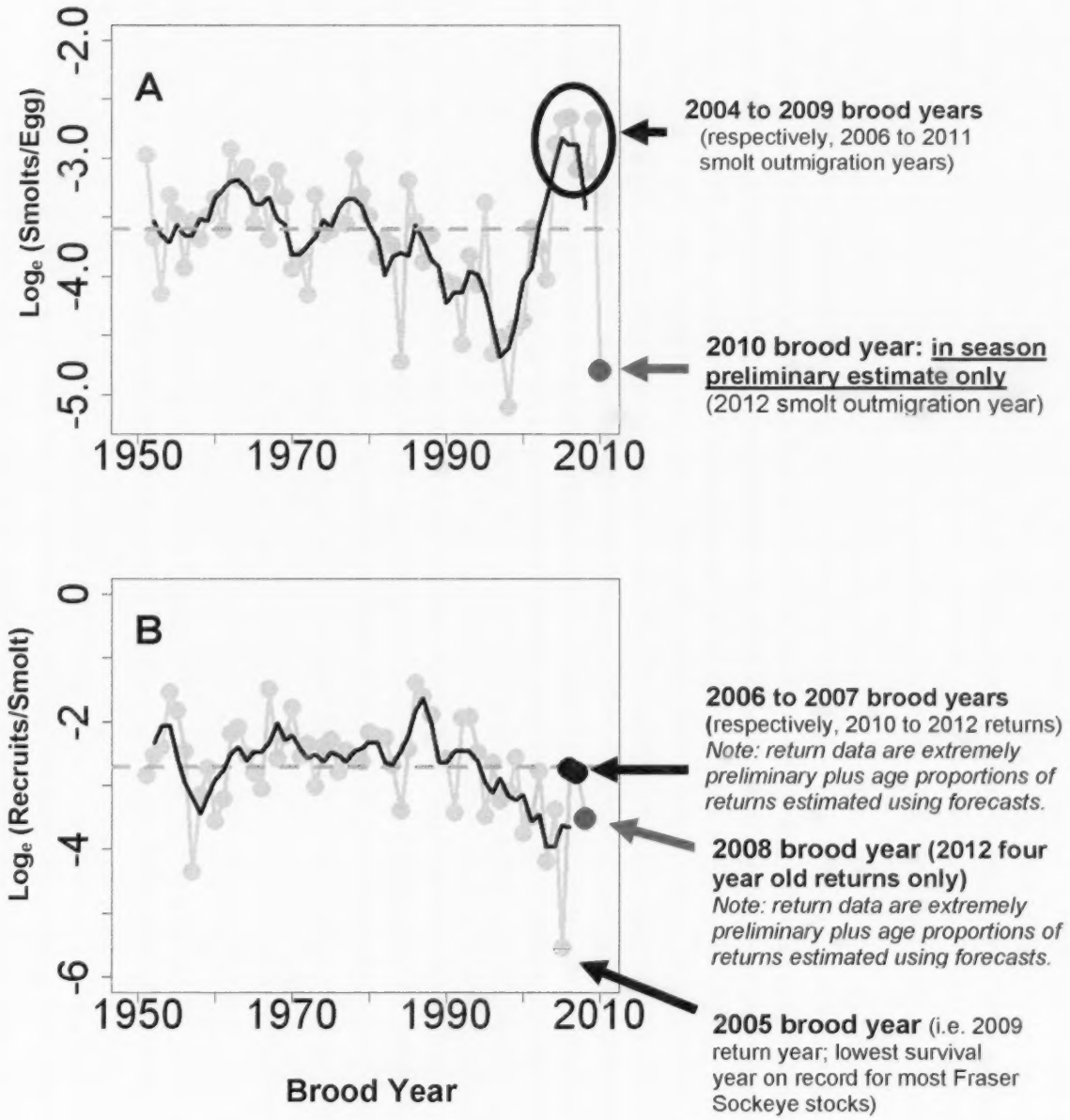

Figure 2. Chilko River Sockeye A. freshwater (log$_e$ smolts per egg) and B. marine (log$_e$ recruits per smolt) annual survival (grey lines) and smoothed four-year running average survival (black lines). Red dashed lines in both plots indicate long-term average survival.

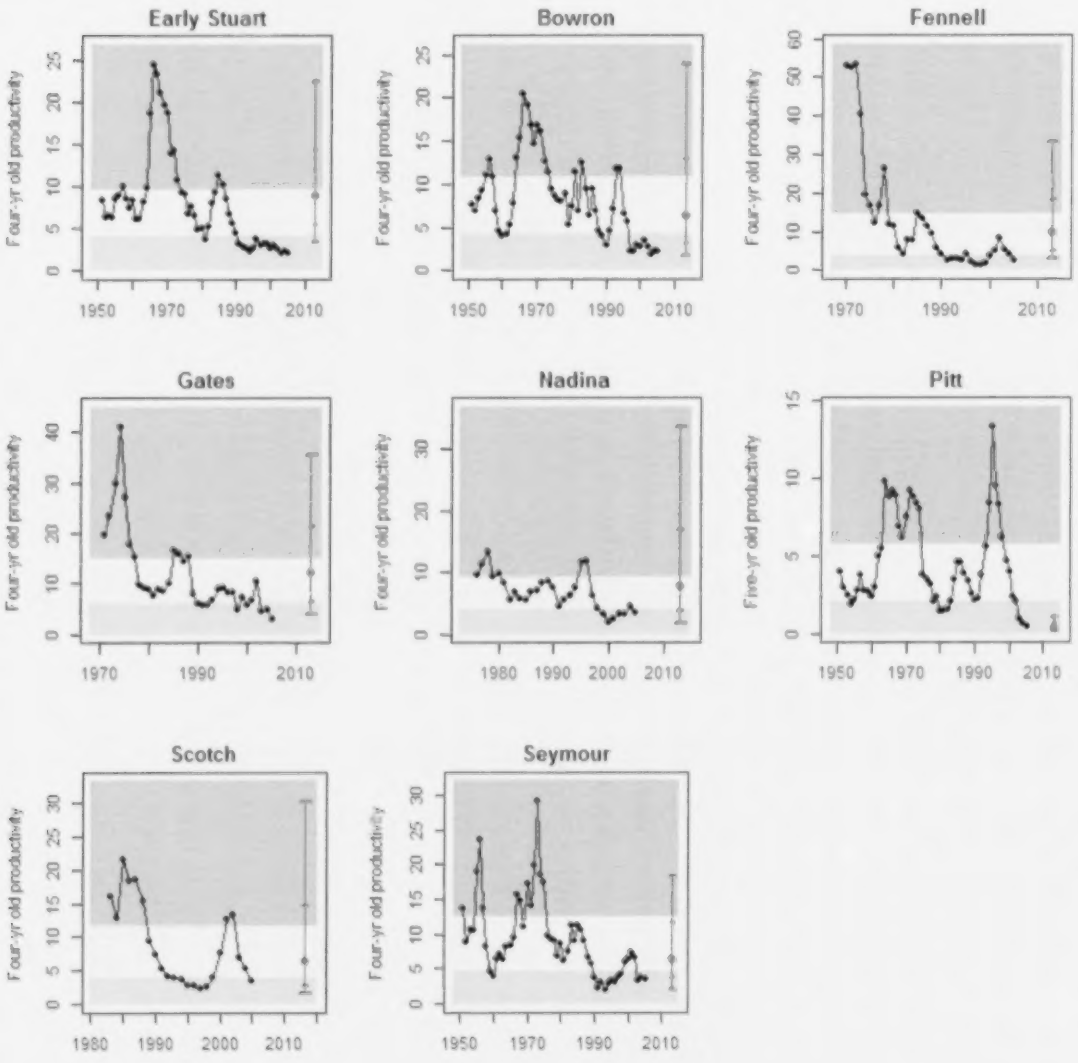

Figure 3. Forecast four year old productivities relative to long-term productivity trends for each stock. Blue lines show the smoothed four year old productivity (four year running geometric mean) using data from the beginning of the time series to the 2005 brood year. For Pitt, five-year old productivity is used. For Quesnel and Late Shuswap, productivity on the 2013 cycle-line is used (not smoothed). For Chilko and Cultus, recruits per juvenile are used. Red bars indicate the range of productivities specified by the 2013 forecasts, at the 10% (lower bar), 25%, 50% (red dot), 75%, and 90% (upper bar) probability levels. Colour codes show where the productivities fall out in terms of the long-term geometric average: Red (< average), yellow (average) and green (>average).

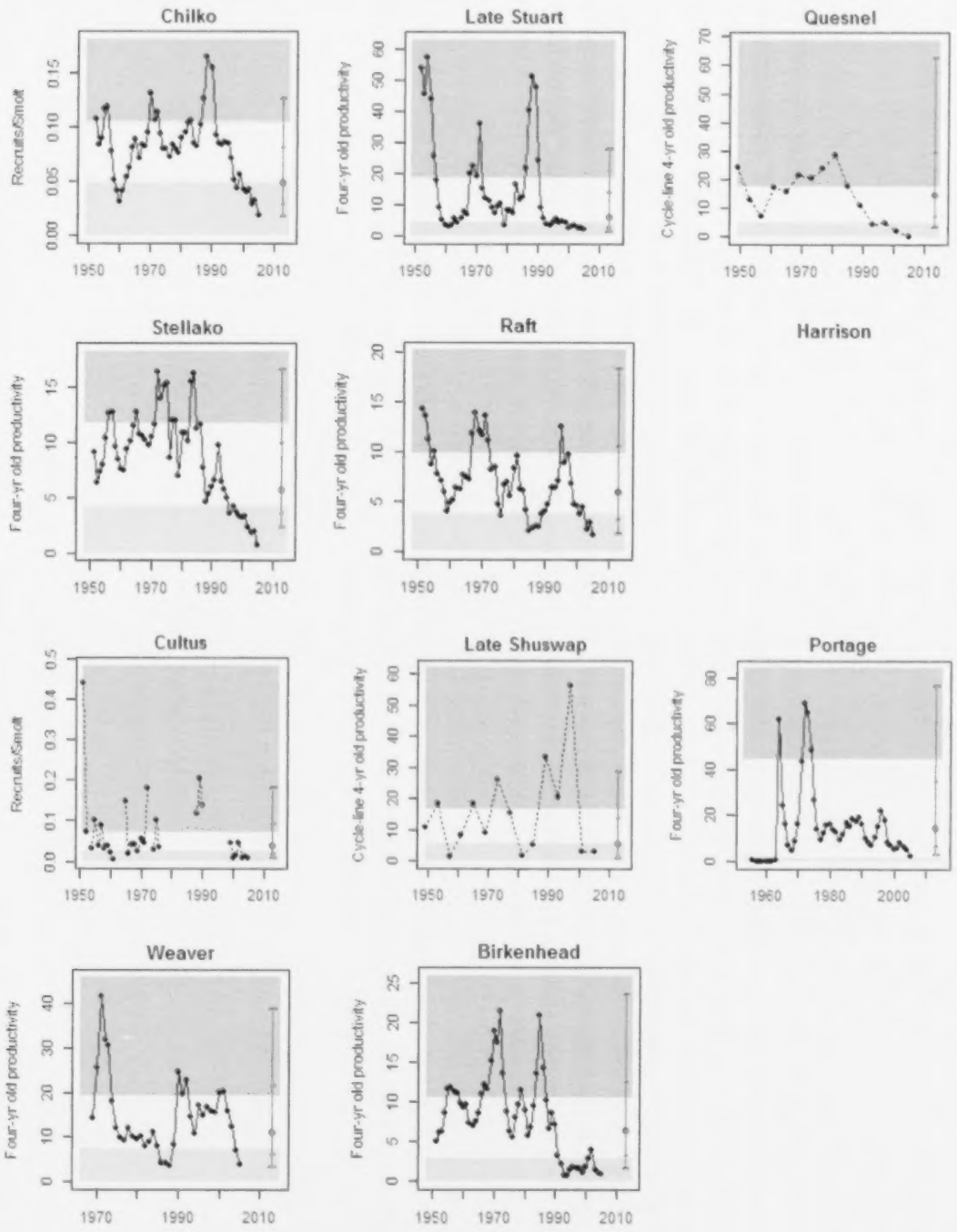

Figure 3. Continued (see previous legend for details)

2009 Forecast and Returns

Run timing group / Stocks	Probability that Return will be at/or Below Specified Run Size [a] 10%	25%	50%	75%	90%
Early Stuart	107,000	165,000	255,000	426,000	645,000
Early Summer	264,000	443,000	739,000	1,338,000	2,284,000
Summer	2,858,000	4,914,000	8,677,000	16,071,000	31,813,000
Late (excl Harrison)	294,000	471,000	838,000	1,456,000	2,502,000
(Harrison Only)	33,000	46,000	69,000	160,000	373,000
TOTAL	4,567,000	7,028,000	11,439,000	18,315,000	29,827,000

2010 Forecast and Preliminary Returns

Run timing group / Stocks	Probability that Return will be at/or Below Specified Run Size [a] 10%	25%	50%	75%	90%
Early Stuart	55,000	8[illegible]0	135,000	213,000	315,000
Early Summer	387,000	723,000	1,518,00[illegible]	3,544,000	7,993,000
Summer	1,434,000	2,304,000	3,972,00[illegible]	6,981,000	11,875,000
Late (excl Harrison)	3,434,000	5,146,000	8,102,000	12,074,000	18[illegible],000
(Harrison Only)	50,000	93,000	262,000	729,00[illegible]	1,923,000
TOTAL	4,567,000	7,028,000	11,439,000	18,315,000	29,827,000

2011 Forecast and Preliminary Returns

Run timing group / Stocks	Probability that Return will be at/or Below Specified Run Size [a] 10%	25%	50%	75%	90%
Early Stuart	21,000	[illegible]0,000	47,000	71,000	100,000
Early Summer	164,000	284,000	518[illegible]	958,000	1,785,000
Summer	1,067,000	[illegible],000	2,464,000	4,138,000	6,579,000
Late (excl Harrison)	411,000	682,000	1,218,00[illegible]	2,247,000	3,985,000
(Harrison Only)	37,000	99,000	380,00[illegible]	1,660,000	2,637,000
TOTAL SOCKEYE SALM	1,700,000	2,693,000	4,627,000	9,074,000	15,086,000

2012 Forecast and Preliminary Returns

Run timing group / Stocks	Probability that Return will be at/or Below Specified Run Size [a] 10%	25%	50%	75%	90%
Early Stuart	39,000	61,000	99,000	161,0[illegible]	270,000
Early Summer	109,000	195,000	359,00[illegible]	665,000	1,214,000
Summer	529,000	828,000	[illegible]420,000	2,449,000	4,160,000
Late (excl Harrison)	46,000	80,000	158,00[illegible]	304,000	589,000
(Harrison Only)	20,000	39,000	83,00[illegible]	184,000	401,000
TOTAL	595,000	939,000	1,670,000	3,194,000	5,867,000

Figure 4. Return versus long-term model performance scenario forecasts from 2009 to 2012. Recent productivity models (RS4yr, RS8yr, KF) were only added to the suite of models evaluated in 2010, and would have been used for particular stock's forecasts depending on their performance over the entire time series. Actual returns are indicated by the coloured circles: red: returns < average productivities (below the 25% probability level forecasts); yellow: returns = average productivities (near the median forecasts from the 25% to 75% probability level forecasts); and green: returns > average productivities (above the 75 % probability level forecasts).

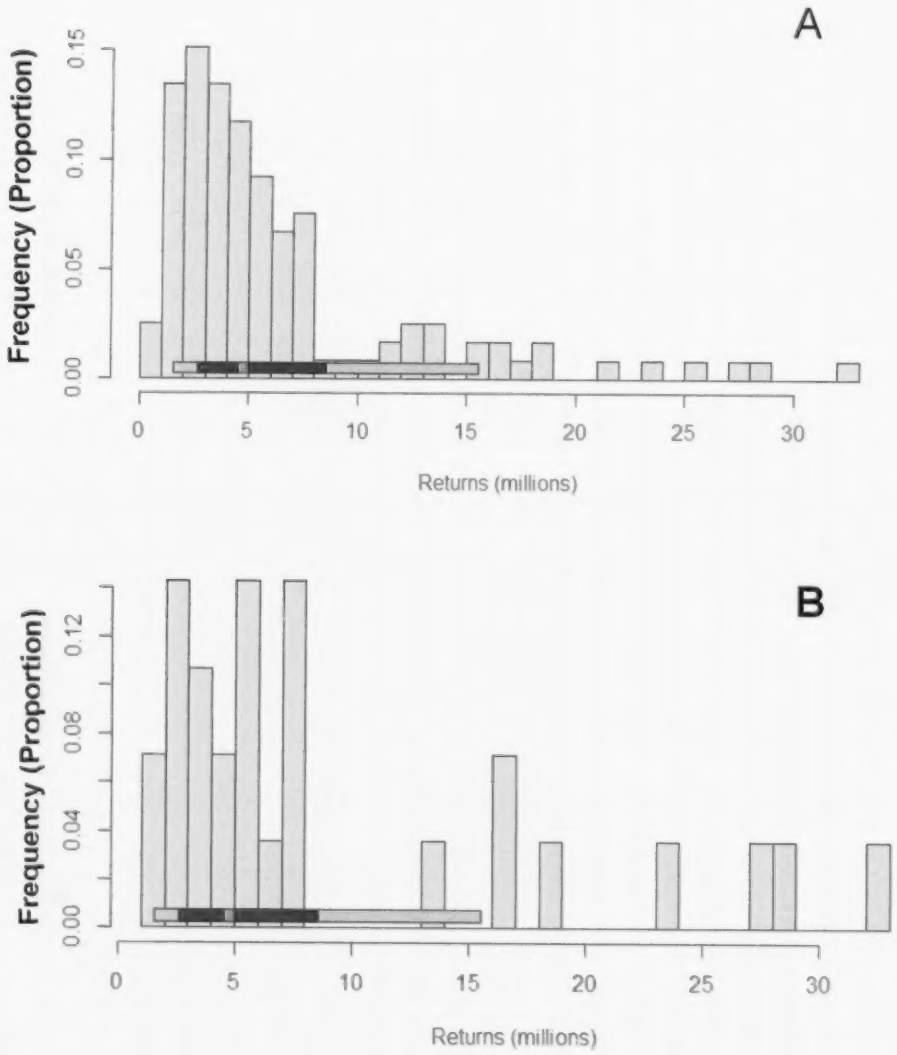

Figure 5. Frequency distributions of historical Fraser Sockeye returns on A. all cycles, and B. the 2012 cycle line. X-axes indicate return abundances in millions and y-axes indicate the frequency (%) of abundances in each interval. Plots are overlaid with the total 2013 forecast cumulative probability distribution, from the 10% to the 90% probability levels. Colour-coding differentiates the probability levels with the full width of the blue bars representing the 10% to 90% probability levels, the width of the black bars representing the 25% to 90% probability levels, and the red vertical line representing the 50% probability level.

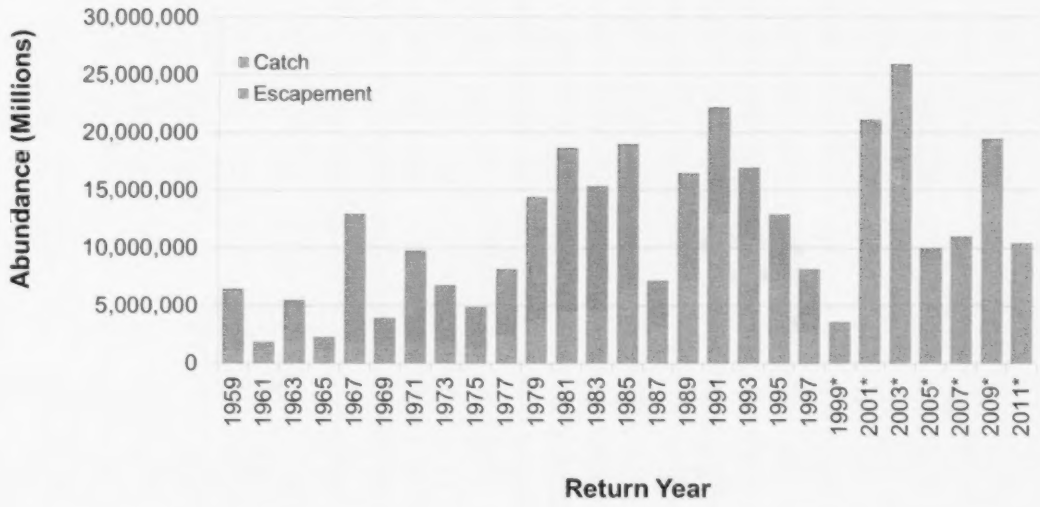

Figure 6. Fraser River Pink Salmon abundance from 1959 to 2011. Enumeration methods have changed considerably over time (years where methods changed are asterisked). For the first part of the time series (1959 to 1997), individual mark recapture escapement programs were conducted on separate systems (e.g. Lower Fraser, Fraser Canyon, Upper Fraser, Seton-Anderson, Thompson, Harrison, Vedder-Chilliwack). Starting in 1999, a single Fraser River system-wide mark recapture Pink escapement program was conducted to 2001. Post-2001, no escapement enumeration programs were conducted, and instead escapement is estimated using total return estimates from test fisheries minus catch.

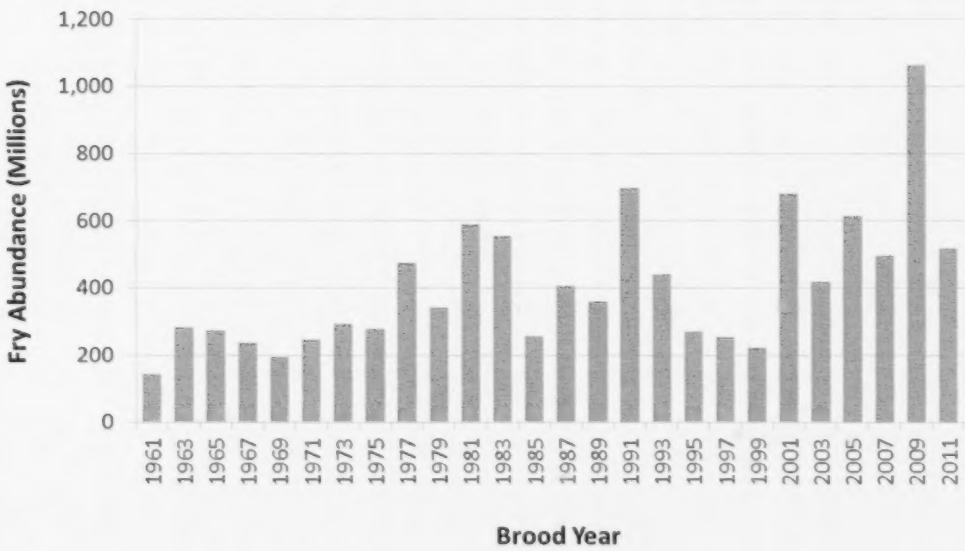

Figure 7. Fraser River Pink Salmon fry abundance from 1961 to 2011.

APPENDIX 1: 'RECENT MODEL PERFORMANCE' SENSITIVITY ANALYSIS

An additional sensitivity analysis was conducted to determine 'Recent Model Performance' forecasts, using the models identified in the 2012 forecast model selection process. This evaluation identified models that specifically performed well over the range of lower productivity seen in the last eight brood years of available data (1997-2004).

Miscellaneous stocks, for which recruitment data are unavailable, were forecast using the product of their brood year escapements and the average recent (brood years 1997-2004) productivity for spatially and temporally similar stocks that have stock recruitment data, as identified in Table 1.

Based on this analysis there is a one in ten chance (10% probability) the Sockeye return will be at or below 523,000, and a nine in ten chance (90% probability) it will be at or below 5.4 million. The mid-point of this distribution (50% probability) is 1.6 million (there exists a one in two chance the return will be above or below this value assuming the productivities implied by the best models evaluated over the recent data set). The total forecast for this sensitivity analysis across all stocks differs from that presented as the 2013 forecast (68% difference between the 2013 forecast and 'Recent Model Performance' scenario at the 50% probability level)

Table A1. Fraser Sockeye "Recent Model Performance" forecasts for 2013 are presented by stock and timing group from the 10% to 90% probability levels (columns A and C to G). The selected models for each stock, as determined by assessing the jack-knife results for 1997-2004, are presented in column B.

A	B	J	K	L	M	N
Run timing group		Probability that Return will be at/or Below Specified Run Size [a]				
Stocks	**Forecast Model** [b]	**10%**	**25%**	**50%**	**75%**	**90%**
Early Stuart	*KF*	**24,000**	**34,000**	**57,000**	**92,000**	**144,000**
Early Summer		**40,000**	**65,000**	**119,000**	**223,000**	**420,000**
(total excluding miscellaneous)		**31,000**	**56,000**	**110,000**	**214,000**	**411,000**
Bowron	*KF*	1,000	2,000	4,000	6,000	10,000
Fennell	*Power*	3,000	5,000	9,000	15,000	25,000
Gates	*KF*	8,000	15,000	27,000	50,000	96,000
Nadina	*MRJ*	10,000	20,000	44,000	95,000	189,000
Pitt	*KF*	1,000	1,000	3,000	7,000	15,000
Scotch	*Larkin*	500	900	2,000	4,000	9,000
Seymour	*Larkin*	7,000	12,000	21,000	37,000	67,000
Misc (Eshu & Taseko)	*RS (Sc/Se)+RS(Chilko)*	2,000	2,000	2,000	2,000	**2,000**
Misc (Chilliwack)	*RS (Esum)*	7,000	7,000	7,000	7,000	**7,000**
Misc (Nahatlatch)	*RS (Esum)*	300	300	300	300	**300**
Summer		**386,000**	**636,000**	**1,095,000**	**2,043,000**	**3,605,000**
(total excluding miscellaneous)		**384,000**	**632,000**	**1,087,000**	**2,022,000**	**3,578,000**
Chilko	*KF(juv)*	233,000	375,000	609,000	1,024,000	1,502,000
Late Stuart	*RS4yr*	15,000	39,000	114,000	333,000	873,000
Quesnel	*KF*	18,000	35,000	72,000	147,000	306,000
Stellako	*Larkin*	91,000	131,000	192,000	291,000	423,000
Raft	*Power*	15,000	24,000	37,000	57,000	89,000
Harrison[d]	*Ricker (Ei)*	12,000	28,000	63,000	170,000	385,000
Misc (N. Thomp. Tribs)	*R/S (Ra/Fe)*	100	300	500	1,400	1,800
Misc (N. Thomp River)	*R/S (Ra/Fe)*	2,000	4,000	7,000	20,000	25,000
Late		**73,000**	**162,000**	**343,000**	**671,000**	**1,250,000**
(total exlcuding miscellaneous)		***71,000***	***154,000***	***334,000***	***656,000***	***1,231,000***
Cultus[e]	*Smolt-Jack (trunc)*	1,000	2,000	3,000	4,000	6,000
Late Shuswap	*Ricker (Pi)*	19,000	57,000	139,000	263,000	478,000
Portage	*KF*	1,000	3,000	6,000	16,000	42,000
Weaver	*MRS*	42,000	76,000	147,000	281,000	506,000
Birkenhead	*RS4yr*	8,000	16,000	39,000	92,000	199,000
Misc. non-Shuswap	*R/S (Lillooet-Harrison)*	2,000	8,000	9,000	15,000	19,000
TOTAL SOCKEYE SALMON		**523,000**	**897,000**	**1,614,000**	**3,029,000**	**5,419,000**
(TOTAL excluding miscellaneous)		***(510,000)***	***(876,000)***	***(1,588,000)***	***(2,984,000)***	***(5,364,000)***

a. Probability that return will be at, or below, specified projection.
b. See Table 5 for model descriptions
c. Harrison are age-4 (column C) and age-3 (column D).
d. Unforecasted miscellaneous Late Run stocks (Harrison Lake down stream migrants including Big Silver, Cogburn, etc.; used Birkenhead R/EFS)
e. Cultus smolt-jack model uses a truncated post-1991 marine survival time series